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DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 26

WASHINGTON
GOVERNMENT PRINTING OFFICE
1899

659117

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

WELLS OF SOUTHERN INDIANA

(CONTINUATION OF WATER-SUPPLY AND IRRIGATION PAPER NO. 21)

BY

FRANK LEVERETT

WASHINGTON

GOVERNMENT PRINTING OFFICE

1899

CONTENTS.

	Page.
Detailed discussion of wells	7
Randolph County	7
Delaware County	9
Madison County	10
Hamilton County	12
Boone County	13
Montgomery County	18
Fountain County	19
Vermilion County	20
Parke County	21
Putnam County	24
Hendricks County	25
Marion County	26
Hancock County	29
Henry County	29
Wayne County	31
Union County	33
Fayette County	34
Rush County	35
Shelby County	37
Johnson County	40
Morgan County	42
Owen County	43
Clay County	44
Vigo County	46
Franklin County	48
Decatur County	49
Bartholomew County	51
Jackson County	53
Scott County	55
Limestone district of southeastern Indiana	56
Knobstone belt of southern Indiana	59
Lower Carboniferous limestone of southern Indiana	60
Conglomerate sandstone of southern Indiana	60
Coal Measures basin of southwestern Indiana	61
Index	63

WELLS OF SOUTHERN INDIANA.[1]

By FRANK LEVERETT.

DETAILED DISCUSSION OF WELLS.

RANDOLPH COUNTY.

General statement.—Randolph County is situated near the middle of the eastern boundary of the State, with Winchester as its county seat. It has an area of 460 square miles.

This county has the distinction of being the most elevated one in the State. Only a small portion of its surface, along the Mississinewa and White rivers, in the northwestern and western parts, falls below the 1,000-foot contour. Several sections in the southeastern part have knolls and ridges rising above the 1,200-foot contour. The highest of these probably reaches 1,250 feet.

The highest land, found in the southern tier of townships, is occupied by a strong morainic belt, having a breadth of 5 or 6 miles and carrying sharp knolls and ridges 30 to 50 feet in height. Between this morainic belt and White River there is a gently undulating plain several miles in width. Immediately north of White River is a small moraine—the Union City ridge—scarcely a mile in average width, which enters the State at Union City and passes westward entirely across the county. This is a gently undulating ridge 25 to 50 feet in height. From this moraine northward to the Mississinewa River there is a gently undulating plain about 6 miles in width. Immediately north of the Mississinewa River is the Mississinewa moraine, which extends slightly into Randolph County.

[1] The present paper is a continuation of Water-Supply and Irrigation Paper No. 21, on "Wells of Northern Indiana," the division of the whole into two papers being rendered necessary by a statutory provision which limits the size of a single paper in this series to 100 pages.

The drift of this county is composed largely of a compact blue till, though in its deeper portions considerable sand is encountered. The thickness ranges from a thin coating up to fully 300 feet. Outcrops of rock occur along the Mississinewa, in the vicinity of Ridgeville, and on White River, near the west line of the county. With these exceptions the drift forms a continuous sheet, and probably has an average thickness of fully 150 feet. Twenty borings in the vicinity of Winchester, where the drift is scarcely so thick as in the southern portion of the county, show an average of 136 feet and a range from 70 to 334 feet.

Individual wells.—Along the Mississinewa moraine, on the north border of the county, several wells show a depth of 90 to 100 feet before entering rock. The drift is mainly a blue till.

At Ridgeville wells penetrate 30 or 40 feet of drift. A few are obtained without entering rock, but the best supply is to be found in the limestone. Many wells are obtained at a depth of only 40 feet.

On the plain between the Mississinewa moraine and the Union City ridge wells are usually obtained at less than 40 feet, and are mainly through till.

The drift in the vicinity of Union City ranges from 60 feet to fully 200 feet. Ordinary wells at Union City are obtained at a depth of about 35 feet in gravel beneath the blue till. The waterworks wells are estimated to yield about 1,500,000 gallons each per day. Two wells supply the city.

At Winchester the dug wells are often obtained at a depth of but 10 or 20 feet, and water is usually struck at 7 to 10 feet. Such wells being liable to contamination, deeper ones have been sunk, which obtain water near the top of the limestone at about 100 feet.

The deepest drift yet discovered in Randolph County was found in two wells about 1½ miles west and northwest from Winchester. In one well rock was struck at 331 feet; in the other at 334 feet. The upper portion of the drift at these wells is till, but the greater part is sand containing water.

Two water wells a short distance south from Winchester—one at Frank Moorman's, the other at Fountain Park Cemetery—do not reach rock at 205 and 210 feet, respectively. One boring in the east part of Winchester does not reach rock at 160 feet. Aside from this, the wells within the city limits of Winchester all enter rock at less than 150 feet, and one at 80 feet.

At Farmland, in the western part of the county, the drift in two gas wells is 58 and 60 feet, mainly till. Water wells are obtained at about 25 feet.

At the village of Parker, also in the western part of the county, water wells usually are obtained at 20 to 60 feet in thin gravel beds between sheets of till. A boring at the grist mill, however, extends to

the rock at 97 feet, and is mainly through till. A gas-well boring in Parker struck rock at 80 feet.

At the village of Windsor, on White River, south from Parker, the drift is mainly sand and gravel, and a gas-well boring shows its depth to be 107 feet.

At Losantville, on the moraine in the southwestern part of the county, the gas boring penetrates 240 feet of drift, some of it gravel, but mainly blue till. Water wells are obtained in that vicinity at 20 to 40 feet, with an occasional tubular well 60 or 80 feet in depth.

At the village of Lynn, in the south part of the county, a gas boring penetrates 117 feet of drift, of which the upper 50 feet is till and the remainder sand and gravel. Another boring in Lynn strikes rock at 124 feet, and its section is similar to the preceding.

The wells on the moraine in southern Randolph County, near the State line, usually obtain water at 20 to 30 feet, occasionally at 50 to 60 feet, in beds of gravel, between sheets of till.

DELAWARE COUNTY.

General statement.—Delaware County is situated in the eastern part of the State, immediately west of Randolph County. It has an area of 400 square miles, and Muncie, its county seat, is situated near its geographic center. The northeastern corner is crossed by the Mississinewa moraine, the eastern part is traversed by the Union City ridge, and the southeast corner is occupied by a strong moraine, the continuation westward of the one noted in southern Randolph County. There are several sharp gravelly knolls in the vicinity of Muncie and an esker of considerable prominence east of Royerton. These moraines and other knolls and ridges are confined to the eastern half of the county. The western half is a gently undulating plain.

The strong moraine in the southeast corner of the county is composed largely of a gravelly drift, but aside from this and the gravelly knolls and the esker above noted the drift of the county is mainly till. Over the greater part rock is usually struck at depths of 50 feet or less, but it is probable that on the moraine in the southeastern corner its thickness may exceed 200 feet. Many gas wells in the vicinity of Muncie enter rock at less than 20 feet, and rock is exposed extensively along the Mississinewa and White rivers in this county. Even if allowance be made for the existence of deep valleys, such as are encountered near Winchester, the thickness of the drift can scarcely exceed 100 feet. It is much less than in the neighboring counties on the north, east, and south, but is similar to the shallow drift of southwestern Grant County and northern Madison County, situated on the northwest and west.

Wells are ordinarily obtained at depths of 20 or 30 feet, either in

gravelly deposits near the base of the drift or in the upper part of the limestone. So far as the writer is aware, there are few if any water wells in the county whose depth exceeds 60 feet.

Individual wells.—At Selma, on the Union City ridge, in the east part of the county, the gas boring penetrates 92 feet of drift, as follows:

	Feet.
1. Yellow till	12
2. Sand with water	8
3. Blue till	12
4. Sand and gravel, becoming coarse near bottom	60
Total	92

At Daleville the drift is 85 feet, but wells are obtained in sand below till at 12 to 16 feet.

Near Wheeling, in the northern part of the county, wells in some cases reach a depth of 35 or 40 feet without entering rock. At Muncie, and also at Shideler and Eaton, wells ordinarily enter rock at 15 or 20 feet.

The waterworks at Muncie obtain their supply from several flowing wells drilled into rock. Three 8-inch wells are estimated to have a combined daily discharge of 50,000 barrels.[1]

MADISON COUNTY.

General statement.—Madison County is situated in the east-central part of the State, immediately west of Delaware, with Anderson as its county seat. It has an area of 450 square miles. The entire county is a gently undulating till plain, across which the drainage lines pass in a westward or southwestward course in narrow channels seldom cut to depths of more than 75 or 100 feet below its surface. The eastern border of the county rises slightly above 900 feet, and the western is fully 800 feet.

Throughout the entire county rock is frequently encountered at depths of 50 feet or less, but occasional borings have shown the existence of valleys deeply filled with drift, which are now completely obscured. The drift is largely a compact till, but affords a sufficient amount of water-bearing gravel and sand to supply the majority of the wells.

Individual wells.—At Summitville, in the northern part of the county, a gas-well boring penetrates 110 feet of drift, of which the upper 15 feet is till and the remainder gravel. Wells are usually obtained in this gravel soon after reaching the bottom of the till. On low ground in the west part of the village the wells pass immediately into the gravel below the surface soil or muck.

A gas well north of Summitville, near the Grant County line, penetrates 70 feet of drift, largely till.

[1] Manual of American Waterworks.

At Alexandria wells are usually obtained in the rock at a depth of about 60 feet. From this depth water rises about 30 feet. The drift at two gas borings in this village is reported to be 22 feet in depth:

	Feet.
1. Gravel	6
2. Blue till	16
Total	22

West from Alexandria the dug wells are ordinarily obtained in the drift at 15 to 20 feet. Tubular wells are somewhat deeper.

At Elwood wells enter rock at depths of about 40 feet, and some obtain water at 75 to 150 feet. In such wells the water usually rises nearly to the level of the bottom of the drift. The waterworks supply is obtained from a well 150 feet in depth and 8 inches in diameter. This well is estimated to yield nearly 20,000 barrels per day. An analysis of the water is given elsewhere.[1]

Several gas borings at Elwood show the drift to range from 40 feet or less up to 108 feet. One well having 56 feet of drift penetrates—

	Feet.
1. Till	15
2. Sand	4
3. Blue till	25
4. Sand	12
Total	56

At Anderson, the county seat, the ordinary wells range in depth from 15 feet to 100 feet. A portion of the city is underlain by gravel, and there is danger of contamination in the shallower wells. In the east part of the city wells in gravel are 60 to 75 feet. In the south and west parts the wells penetrate till to a depth of 50 to 100 feet before obtaining a strong supply of water. The city waterworks obtain the supply from the White River, but the water is not considered suitable for domestic purposes, being used only for lawns and streets and in baths. Several fountains are maintained in the city by pumping water from a deep well in White River Valley, near the waterworks pumping station. It is forced to the fountains by a pump connected with the waterworks engine. This well is reported to have an inexhaustible supply, and is objectionable only because of the sulphureted hydrogen which its water contains.

The gas wells in Anderson have drift ranging in thickness from 16 feet to nearly 200 feet. At a well in the west part of the city, in White River valley, 194 feet of drift is penetrated. At the crossing of the Panhandle and the Cincinnati, Wabash and Michigan railways, on the bluff north of the river, 191 feet of drift was penetrated. A well three blocks southwest of the court-house penetrates 91 feet of drift,

[1] *Eighteenth Ann. Rept. U. S. Geol. Survey*, Part IV, p. 498.

entirely gravel. At the court-house the drift is 48 feet, and is entirely gravel. A well west of the crossing of the Bee Line and Panhandle railways penetrates 104 feet of drift, of which the upper 34 feet is sand and gravel, and the remainder blue till.

In several wells on the plain 2 or 3 miles southeast of Anderson, a bluish-black muck, resembling a soil and carrying considerable wood, is reported to occur at depths of 20 to 40 feet.

At Frankton, in Pipe Creek valley, about 6 miles northwest from Anderson, a gas boring penetrated 85 feet of drift.

At Huntsville and Pendleton, in the valley of Fall Creek, about 8 miles south of Anderson, rock outcrops occur, but the drift in some cases is 90 feet.

At Markleville, in the southeast corner of the county, a gas well penetrates 147 feet of drift. Water wells in that vicinity are obtained at 20 to 40 feet, and often encounter a blue mud, carrying wood.

HAMILTON COUNTY.

General statement.—Hamilton is the center county of the State, with Noblesville as its county seat, and has an area of 400 square miles. The White River valley traverses the southeastern part of the county. The only other streams of importance are Cicero Creek, which enters White River from the north, near Noblesville, and Fall Creek, which touches its southeastern corner. The eastern two-thirds of the county is nearly level and stands about 800 to 850 feet above tide. In the western third there is a gradual rise to a higher plain, 900 to 950 feet, which occupies much of Boone and Clinton counties. This rise is occasioned, not by greater elevation of the underlying rock, but by a thickening of the drift deposits. Indeed, the general rock surface lies lower in the western part of the county than in the central and eastern, as shown by numerous gas-well borings. The upper portion of the drift in this county is principally a compact till, but there are small areas bordering the valley of White River in which the till is replaced by gravel. There are also gravelly terraces along the stream. The deeper portions of the drift throughout the county appear to carry large amounts of gravel and sand.

Individual wells.—In the vicinity of Noblesville the drift has a known range from 33 feet to 186 feet, the shallowest drift being found about a half mile north of the court-house, in the valley of White River, and the deepest about 2 blocks north of the court-house, at the Evans well. In both wells it is mainly gravel. A well in the valley, 1½ miles north of the court-house, penetrates 176 feet of drift, mainly gravel, but having 40 feet of red clay at bottom. Several wells about 2 miles east of Noblesville also penetrate a gravelly drift and enter rock at about 80 feet. A well 1½ miles west of this city penetrates 98 feet of drift, mainly till.

The dug wells in the city of Noblesville obtain the first vein of water at about 20 feet, but a greater quantity and better quality is obtained at a depth of 65 or 75 feet. Wells are therefore often bored to that depth. The city waterworks contains an inexhaustible supply from such wells at a depth of 70 or 80 feet.

At Cicero, 6 miles north of Noblesville, two gas wells reach rock at 141 and 161 feet, and are mainly through till. A well 1 mile south of Cicero penetrates 270 feet of drift, largely sand and gravel, but with 60 feet of hard reddish till at the base.

At Fishers Station, 6 miles south of Noblesville, a gas well penetrates 110 feet of drift.

At Carmel the drift is only 96 feet, but at Westfield, about 5 miles west of Noblesville, one gas well strikes rock at 196 feet and another at 220 feet. The drift is mainly till in both wells. A well 3 miles southeast of Westfield penetrates—

1. Drift	95
2. Till	20
3. Sand and gravel	75
Total	190

At Eagletown, in the west part of the county, a gas-well boring penetrates 200 feet of drift:

	Feet.
1. Till	160
2. Sand and water	20
3. Red clay	20
Total	200

At Jolietville the drift is about 200 feet and mainly till.

At Sheridan a gas well penetrates 233 feet of drift:

	Feet.
1. Till	150
2. Sand and gravel, with water	40
3. Red clay, with white pebbles	43
Total	233

In the east part of the county, at Clarksville, a gas well enters rock at 16 feet, but one a mile north of the village penetrates 82 feet of drift, mainly till.

From the deep sections above given it should not be inferred that water wells are difficult to obtain, for throughout much of the county an abundance of water is found at convenient depths, wells seldom exceeding 40 feet.

BOONE COUNTY.

General statement.—Boone County is situated in the central portion of the State, immediately west of Hamilton, with Lebanon as its county seat. It has an area of 420 square miles. Its elevation is somewhat greater than the counties to the east or west, and the water parting between the Wabash and White rivers traverses its central

portion from north to south. The elevation of this divide is due not to the high altitude of rock strata, for gas borings have shown that the rock strata have a greater elevation on the slope toward the Wabash in western Boone County and in Montgomery County than along the divide. So far as known to the writer there are no outcrops of rock in the county. There is in the eastern and central part of this county, as in the counties to the east and north, a deposit of drift 250 to 300 feet or more in thickness. The surface of the county is almost entirely plane, there being only occasional low swells and ridges scarcely exceeding 20 feet in height.

Individual wells.—In the following list of wells are included sections of several published by Messrs. Gorby and Lee in the fifteenth report of the State geologist. But few well records were personally obtained.

In sections given by Gorby and Lee it appears that in the northwestern part of the county there is in many places a bed of sand between the yellow and blue till. In some cases the sand is but 3 or 4 feet in thickness, but it occasionally reaches a thickness of over 50 feet. There is usually below this sand a thick bed of blue till 50 to 150 feet. The following wells serve to illustrate the above statements. Witt and Klizer's well at Thorntown penetrates—

	Feet.
1. Yellow clay	21
2. Quicksand	4
3. Blue clay	125
4. Shale, limestone, etc	193
Total	343

Mr. Duke's well, 3 miles north of Thorntown, penetrates—

	Feet.
1. Yellow till	18
2. Quicksand	12
3. Blue clay	153
4. Red sandstone	3
Total	186

A neighboring well at Mr. Wetherald's has a similar section. A well near Union Church, 3 miles east of Thorntown, penetrates—

	Feet.
1. Yellow till	27
2. Quicksand	9
3. Blue till	75
Total	111

Mr. Frank Harris's well, 1 mile south of Thorntown, penetrates—

	Feet.
1. Yellow till	19
2. Quicksand	4
3. Blue till	103
4. Cemented gravel	16
Total	142

William Mills's well, 1 mile west of Thorntown, penetrates—

	Feet.
1. Yellow till	25
2. Quicksand	3
3. Blue till	80
Total	108

At Charles Moffit's, 1½ miles west of Thorntown, a dry gravel was penetrated for 44 feet from the surface and the boring abandoned without obtaining water. Robert Woody's well, 3½ miles west of Thorntown, penetrates—

	Feet.
1. Yellow till	18
2. Fine white sand	55
3. Blue till	71
4. Limestone	3
Total	147

In the vicinity of Sugar Creek, near the west boundary of the county, the drift is only 20 to 40 feet in thickness, and is underlain by cherty limestone.

Wells are usually obtained in the village of Thorntown at 20 to 28 feet, and some wells at a depth of only 14 feet. In the valley bottom wells are mainly through sand and gravel, but on the bluffs they have sections similar to those noted above.

In the vicinity of Northfield, in the northeastern part of the county, wells are usually obtained in sand or gravel below a yellow till, at depths of 20 to 40 feet. In the vicinity of Slabtown, in the eastern part of the county, the water is obtained at depths varying from 20 feet to 50 feet. In this locality some blue till is usually penetrated above the water-bearing gravel.

A well about midway between Slabtown and Elizaville is reported to have penetrated a swamp muck below till at a depth of about 60 feet. The following section is reported by the well borer, Mr. Ball, of Thorntown:

	Feet.
1. Yellow till	18
2. Quicksand	3
3. Blue till	20
4. White sand, with inflammable gas	11
5. Blue clay	6
6. Swamp muck, leaves, twigs, etc	7
7. Blue clay	19
Total	84

A similar swamp muck was penetrated by Mr. Ball in a well for Mr. Vandeveer, 6 miles south of Lebanon. The well penetrates—

	Feet.
1. Yellow till	20
2. Blue till	45
3. Swamp muck, leaves, twigs, etc	10
4. Blue clay	25
5. Sandstone	9
Total	109

A similar muck was found at 48 to 60 feet in a well 4 miles north of Jamestown, and at 60 to 63 feet in a well 2½ miles north of Jamestown.

At the village of Roston, east of Lebanon, wells are usually obtained at from 8 to 20 feet in sand and gravel below a red clay.

In the vicinity of Ratsburg, northeast of Lebanon, water is usually obtained in sand below a gray till at about 20 feet.

At Lebanon the wells are but 12 to 24 feet in depth, with an average of about 16 feet. They are obtained in gravel, which has scarcely a sufficient amount of clay cover to insure freedom from surface contamination. The waterworks wells, however, are deeper.

A gas-well boring in the city of Lebanon penetrates 342 feet of drift. The specimens of the different kinds of material were examined by the writer, and the following section was determined:

	Feet.
1. Black soil	2
2. Yellow till	9
3. Blue till	15
4. Sand, with water	1½
5. Ash-colored till	77
6. Gravel	8
7. Pale ash-colored till	50 to 55
8. A darker ash or gray till, with some sand interbedded	176
Total	342

Below the drift is shale, 108 feet in depth, beneath which limestone of great thickness is penetrated.

Messrs. Gorby and Lee report the section of a well on Washington street, in Lebanon, 108 feet in depth, in which the structure is remarkably variable, as follows:

	Feet.
1. Soil (probably clay)	7
2. Yellow sand	1
3. Yellow clay	3
4. Blue sandy clay	1
5. Sand	4
6. Blue clay	3
7. Sand and gravel	4
8. Blue and gray clays	26
9. Sand and clay	10
10. Blue clay	23
11. Coarse gravel	1
12. Blue clay	25
Total	108

A well on D. M. Burns's farm, 2 miles north of Lebanon, is reported to penetrate—

	Feet.
1. Soil and yellow till	9
2. Gravel and sand	2
3. Blue till	22
4. Gravel	2
5. Gravel and clay	3
6. Blue till	74
Total	112

A well 4½ miles northeast of Lebanon enters rock at a depth of 285 feet. The section of drift was not ascertained.

A well on the farm of Clairborne Cain, 5 miles west of Lebanon, failed to reach rock at a depth of 243 feet. It penetrates—

	Feet.
1. Soil and yellow till	17
2. Quicksand	5
3. Blue till	51
4. Dry gravel with inflammable gas	5
5. Blue till	165
Total	243

Obstructions in the pipes made it necessary to abandon the boring without reaching the bottom of the blue till.

At the village of Jamestown wells are usually obtained at 25 to 30 feet. Gorby and Lee report the following sections at two deeper wells at this village. A well at the sawmill in Jamestown penetrates—

	Feet.
1. Soil and yellow till	11
2. Quicksand	1
3. Blue till	28
4. Gravel	2
5. Blue till	48
Total	90

A well at the gristmill in Jamestown penetrates—

	Feet.
1. Yellow till	11
2. Sand	2
3. Blue till	49
Total	62

Wells at New Brunswick are reported to obtain water at 11 feet to 35 feet. They usually penetrate considerable gravel in the upper 10 to 15 feet, below which there is a blue clay extending to the waterbed.

At Milledgeville the wells range in depth from 12 feet to 42 feet, and obtain water in sand and gravel between beds of till.

At Royalton water is usually obtained at depths varying from 10 feet to 40 feet. Foster and Leap had a well bored to the depth of 96 feet, penetrating—

	Feet.
1. Soil and yellow till	20
2. Gravel	5
3. Blue till, with frequent thin beds of sand and gravel	71
Total	96

A well at a sawmill in the same village, 107 feet in depth, had a similar section.

At Zionsville the wells are 20 to 60 feet, and are usually obtained from thin beds of gravel between till sheets. A gas-well boring in Eagle Creek Valley, near Zionsville, penetrates 165 feet of drift, of which the upper 40 *feet is mainly* sand and gravel and the remainder *mainly blue till.*

MONTGOMERY COUNTY.

General statement.—Montgomery County is situated in the west-central portion of the State, with Crawfordsville as its county seat. It has an area of 504 square miles. The altitude is somewhat uniform, the greater part of the county standing between 800 and 900 feet above tide. The surface is generally plane, or but gently undulating. In the northwestern part, however, there are morainic belts of considerable prominence. Moraines of gentle expression also occur east and southeast of the strong belts and traverse the eastern part of the county. The thickness of the drift is much less than in Boone County, rock being exposed on many of the streams at levels 50 feet or less below the bordering upland. There are, however, very deep valleys traversing the county, whose courses do not coincide with those of the present system and which are so completely obscured by the drift deposits which fill them as to be known only where deep borings have been made in them. One of these valleys is brought to light by borings in the vicinity of Crawfordsville. The drift of this county is apparently, in the main, a compact till, in which only thin beds of sand or gravel occur. Exposures along Sugar Creek, in the vicinity of Crawfordsville, show sheets of different constitution and age, testifying to more than one invasion of the ice. The county is well supplied with springs along its valleys, some being from limestone ledges and some from gravel in the Glacial drift.

Individual wells.—Over much of the northern part of the county wells are obtained at depths of 12 to 20 feet in beds of sand or gravel below the yellow till. They seldom reach a depth of 50 feet. A well at Pleasant Hill, in the northwest corner of the county, 47 feet in depth, penetrates a soft till for 37 feet, beneath which a much harder till is encountered.

Along a morainic belt in the western part of the county, near Alamo, wells occasionally reach a depth of 70 feet, mainly through till.

In the vicinity of Crawfordsville several gas wells have been drilled. One at Crawfordsville Junction penetrates 140 feet of drift, as follows:

	Feet.
1. Yellow till	12
2. Soft blue till	60
3. Hard blue till with gravelly beds	64
4. Gravel	4
Total	140

An attempted boring in section 33, near Crawfordsville, penetrated till 50 feet and then entered a bed of quicksand, which continued at least to a depth of 240 feet, where the well was abandoned. A boring in Sugar Creek Valley, near Crawfordsville, has about 200 feet of drift, mainly sand and gravel. Near the bottom there was a gray silt or

mud. In this connection it should be noted that rock outcrops occur within a mile north of Crawfordsville at a higher elevation than the mouth of the gas boring just mentioned.

The waterworks at Crawfordsville obtain the main supply from Van Cleve's springs. The water is collected in an impounding reservoir, from which it is pumped to the standpipe. Wells are also drawn upon, but the depth has not been ascertained. The private wells of the city vary greatly in depth and are obtained from beds of sand or gravel between sheets of till.

In the southern half of the county wells ordinarily obtain water at 25 to 30 feet in gravel or sand beds associated with the till. Blue till is entered at about 15 feet. Wells 50 feet in depth are rare. Near Wayland rock is sometimes struck at 20 or 30 feet, but a well in the village does not reach rock at 50 feet.

FOUNTAIN COUNTY.

General statement.—Fountain County is situated near the middle of the western part of the State, immediately south and east of the great bend of the Wabash River, that stream forming its north and west boundaries. The area is 390 square miles. Covington, the county seat, is situated at the west line of the county.

The greater portion is a very smooth plain underlain by till. There are, however, small morainic ridges traceable across the county. One leads in a southeastward course from Attica across its northeastern corner. This belt has a width of 2 or 3 miles and consists of a series of knolls and low ridges seldom more than 25 feet in height and rather loosely aggregated. A narrower morainic line is found along Coal Creek, in the southwest part of the county. This belt apparently separates into two, one of which follows the west border of Coal Creek northward to the Wabash, while the other passes eastward, through Rynear and Hillsboro, into Montgomery County.

Throughout much of the county rock is encountered at depths of 40 or 50 feet or less. Many wells in the northern portion find their water at the base of the drift at about 20 feet. Nearly all the streams of the county have outcrops of rock along them at levels only 30 to 50 feet above the bordering uplands. It is thought that the average thickness of the drift can not much exceed 50 feet.

There are numerous strong springs along the Wabash, issuing either from sandstone or from drift gravel.

Individual wells.—At Attica a strong artesian well has been obtained in the valley of the Wabash River, which supplies an excellent quality of water amply sufficient for the city. A large part of the population are in the habit of obtaining water from this well. A satisfactory record of the boring could not be obtained at the time of my visit, but it enters rock strata.

On the uplands *south of Attica* wells are usually obtained at 27 to

35 feet and are mainly through till. In some localities, however, as in secs. 1 and 2, T. 20, R. 8 W., wells enter sand below till at a depth of but 10 to 15 feet and continue in sand to a depth of 25 to 40 feet, where water is obtained. In section 11 of this township wells strike shale at 18 to 20 feet. In section 8 they enter blue till at 6 or 8 feet and reach a water-bearing sand at 15 feet to 25 feet. One well on the Wabash bluffs, near Attica, in sec. 34, T. 22, R. 7 W., reaches a depth of 60 feet without encountering rock.

Wells on the uplands east of Stone Bluff enter rock at about 20 feet. In the valley of Coal Creek, at Stone Bluff and Chambersburg, water is obtained in gravel and sand at a depth of 30 or 35 feet.

At Veedersburg the wells vary in depth from 20 feet up to 70 feet. They are mainly through blue till and seldom strike rock.

At Covington wells are obtained in gravel at 50 or 60 feet. The waterworks supply is from springs. An artesian well boring near the court-house, at an altitude 65 feet above low water in the Wabash, has a depth of 358 feet, terminating in the conglomerate sandstone. It penetrates 85 feet of drift, of which the upper 74 feet is gravel and the lower 11 feet blue till. The well does not overflow. The water is called "sulphur water." But little use is made of it at present.

Several wells in Mill Creek Township, in the southern part of the county, are reported to enter a black muck below till at about 25 feet. Beneath this muck is another till sheet harder than the one above it.

Borings for coal in the northeastern part of Fountain County are reported by Dr. Brown[1] to reach a depth of 100 to 130 feet in several cases before entering rock, though in the vicinity rock is usually found at 20 to 40 feet from the surface.

A salt-well boring in sec. 4, T. 18, R. 8 W., was sunk to a depth of 1,004 feet and passed several veins of salty water, the first being at a depth of only 72 feet. The drift at this point is 40 feet in depth.

A boring near Lodi, on the southern border of the county, was sunk to a depth of 1,155 feet, and obtains a strong flow of salt water. There is also a strong flow of sulphur water, struck at a depth of 1,051 feet. The analysis of the water from this well is given elsewhere.[2]

VERMILION COUNTY.

General statement.—Vermilion County is situated near the middle of the west border of the State, and occupies a narrow strip between the Wabash River and the State line, the length of the county being 36 miles and the width 6 to 10 miles. Its area is 270 square miles. The greater part of the county is a till plain, standing about 200 feet above the Wabash River. It is crossed, however, from west to east by two small moraines, one following the south border of the Big Vermilion Valley, the other the south border of the Little Vermil-

[1] Eleventh Ann. Rept. Indiana Geol. Survey, p. 92.
[2] *Eighteenth* Ann. Rept. U. S. Geol. Survey, Part IV, p. 498.

ion. The former comes to the Wabash Valley at Eugene, the latter at Newport, the county seat. In the northern portion of the county the gravel terraces of the Wabash, standing 75 to 100 feet above the river, extend back a mile or more from the stream. There are also extensive remnants of the gravel terrace near Clinton, in the southern part of the county.

Individual wells.—On the till plain, in the northern part of the county, wells enter a blue till at about 6 or 8 feet, and obtain water in the beds of gravel or sand associated with the till at depths of 15 to 25 feet. There are very few deep wells, though the record of one 56 feet in depth was obtained. This is situated near the State line, in the northwest corner of the county, and is mainly through blue till.

Wells on the gravel terrace of the Wabash, in the northern part of the county, are often sunk to depths of 60 or 80 feet, and occasionally 100 feet, through sand and gravel, before entering a water bed. In passing westward from the river the gravel becomes shallower, and till is encountered before reaching the level of the river. It is not rare to find beds of muck containing wood and leaves at the base of the gravel. This muck is thought to be an interglacial flood-plain covered by glacial gravels of a later invasion.

In the villages of Eugene and Cayuga, which are situated on a low terrace of the Wabash near the mouth of Big Vermilion River, wells are ordinarily obtained at 40 feet or less, at about the level of the Wabash River.

On the uplands west of Eugene, in section 8, and at an altitude about 160 feet above the Wabash River, a boring 241 feet in depth failed to reach rock or obtain water. It was mainly in a compact blue till.

At Newport the wells range in depth from 12 feet to 88 feet, and obtain water in gravel between sheets of till.

At Clinton wells are usually sunk to a depth of 60 to 75 feet in gravel, and obtain water at about the level of the Wabash River. A boring for coal at this village, made on the low bottom of the Wabash, penetrated 100 feet of drift before entering rock.

On the uplands, in the southern part of the county, wells are ordinarily obtained at about 30 feet, in gravel between till sheets.

PARKE COUNTY.

General statement.—Parke County is situated in western Indiana, immediately opposite the southern portion of Vermilion County, on the east side of the Wabash River. It has an area of 440 square miles. Rockville is the county seat.

Several large creeks traverse the county in a northeast to southwest direction in valleys cut to a level 100 to 150 feet below the bordering uplands, and these streams, with their numerous tributaries, cause a somewhat broken surface. Between the streams, however,

there are strips of level upland, preserving the original elevation of the plain. A series of drift ridges traverse the central portion of the county in a northeast to southwest direction. These ridges are but 30 to 50 feet higher than bordering plains and have a gently undulating surface. They are, therefore, not conspicuous features.

The southern portion of this county extends beyond the limits of the Wisconsin drift sheet and its surface is covered with a nearly pebbleless white clay, several feet in thickness, which rests upon a sheet of older drift of Illinoian age. The central and northern portions of the county and a narrow belt along the Wabash, in the southern portion, are covered by the later sheet of till. Wells are often obtained at the junction of the two drift sheets at depths of 20 to 40 feet on plane tracts and somewhat greater depth on the moraines or drift ridges. The later drift is readily distinguished from the earlier by its softness and its fresher appearance. Wells may be readily spaded or bored in the newer drift, while in the older a drill or pick must be substituted. The hardness of the older till sheet is largely due to a partial cementation with carbonate of lime.

The thickness of the drift varies greatly, not because of variation in the surface elevation, but because of the greatly eroded rock surface upon which the drift lies. There are numerous outcrops along streams at levels only 50 to 75 feet below the general level of the upland, but it is probable that the average thickness of the drift of the county exceeds 100 feet.

Springs are not so numerous or strong as in the adjoining counties, Fountain and Montgomery, and are not an important water resource.

Individual wells.—Wells are usually obtained in beds of sand and gravel, between sheets of drift or near the base of the drift, at depths varying from 10 or 15 feet up to 100 feet or more. The knowledge of the thickness of drift is obtained from coal shafts or test borings for coal rather than wells, there being numerous shafts and borings in the southern part of the county.

In the northeastern part of the county, on the plain north of Sugar Creek, wells are usually obtained at about 30 feet. They enter blue till at 12 or 15 feet.

On the plain south of Sugar Creek records of several wells show a depth of 30 to 36 feet, but in the village of Annapolis the wells seldom reach 30 feet.

In the northwest part of the county, on the bluffs of the Wabash, wells are occasionally 50 feet in depth. One of these wells, a mile north of the mouth of Sugar Creek, at an altitude 150 feet above the Wabash River, has the following section:

	Feet.
1. Sand	8
2. Gravel	10
3. *Sand*	25
4. *Blue till*	5
Total	48

The amount of sand at this point is exceptional, though there is generally a narrow belt of sand along the immediate brow of the bluff.

At the village of Howard, on a terrace 80 feet above the Wabash, wells obtain water near the bottom of the gravel at about 40 or 50 feet. At Lodi, on a lower terrace, 35 feet above river level, wells are obtained at 35 or 40 feet. Near West Union, also on a high terrace, wells obtain water at 75 feet, or about the river level.

At Montezuma an artesian well 1,707 feet in depth, situated on a terrace of the Wabash about 50 feet above the river, penetrates 128 feet of drift. Salt water was struck at a depth of 298 feet and at lower levels, and sulphur water at 1,205 feet. The water has a head at least 100 feet above the mouth of the well. The ordinary wells at Montezuma are usually obtained at a depth of about 60 feet in the gravel, but have a range from 30 feet to 70 feet.

At Bloomingdale wells are obtained at a depth ranging from 12 feet to fully 60 feet. Ordinarily the water-bearing sand and gravel is found beneath the yellow till at 10 to 16 feet. The deeper wells penetrate blue till. Sandstone is occasionally struck at about 50 feet.

On a morainic ridge near Marshall wells are usually obtained at 30 feet or less.

In the vicinity of Bellmore wells sometimes enter rock at about 30 feet. Usually water is obtained without penetrating the rock.

At Rockville, the county seat, there is no definite horizon at which wells are obtained, those on adjoining lots varying greatly in depth and in the character of material penetrated. The depth ranges from 15 feet to about 75 feet. Ordinarily wells reach the bottom of the newer drift at about 25 feet, and encounter considerable wood at that horizon. A gas-well boring located in the higher part of town penetrates 96 feet of drift. A well on the moraine just west of Rockville has 158 feet of drift, of which the upper 35 or 40 feet is newer drift and the lower 125 feet is the older drift. A well 2 miles southwest of Rockville, 92 feet in depth, penetrates a soft till 17 feet, beneath which is a hard till whose bottom is not reached.

The city of Rockville contemplates waterworks from deep wells bored in a valley east of the city. Two borings 260 feet in depth have been sunk for the purpose of obtaining a supply, but the supply scarcely seems adequate.

Wells along the morainic ridge on the east bluff of the Wabash River in the south part of the county have in several instances passed through a black soil below the newer till sheet at about the level of the base of the morainic ridge. The distance to the soil varies in the different wells with the variations in elevation of the ridge, and there is a known range from 17 to 75 feet. Often water is obtained at slight depth beneath this buried soil from the upper portion of the older drift sheet.

On the uplands west of Rosedale coal shafts penetrate 50 to 75 feet

of drift, mainly till and entirely in the older drift sheet. Wells are obtained in the village of Rosedale at depths of 12 to 25 feet.

In the southeastern part of the county coal shafts often encounter much sand and gravel in the lower portion of the drift at depths of 30 to 60 feet from the surface. Wells range in depth from 20 to 100 feet, but are usually obtained at less than 30 feet. Mr. Minchell's well, in section 30, Jackson Township, 62 feet in depth, penetrates—

	Feet.
1. Surface clay and till	15
2. Hard blue till	45
3. Sand with water	2
Total	62

A boring in section 24 of an adjoining township on the west, 96 feet in depth, penetrates—

	Feet.
1. Surface sand	17
2. Hard blue till	29
3. Sand and gravel	10
4. Hard blue till	16
5. Sand and gravel	4
6. Hard blue till	20
Total	96

PUTNAM COUNTY.

General statement.—Putnam County is situated in the west central part of the State, with Greencastle as its county seat. It has an area of 490 square miles. The southern portion of the county is moderately hilly, there being insufficient drift to fill the preglacial valleys. The northern portion, although nearly as elevated as the southern, has a comparatively smooth surface, a result of the greater amount of drift filling. The hilly southern portion of the county carries only the older drift sheet. The northern portion carries also the newer drift. The southern boundary of the newer drift passes from northwest to southeast across the central portion of the county, entering on the west about 10 miles from its north boundary and leaving the county on the east about 5 miles from its south boundary. The city of Greencastle is situated very near the border of this later sheet of drift. Both drift sheets are composed largely of till, but, as in Parke County, the older drift is much harder to penetrate than the newer. The thickness of drift in the portion where both sheets are present probably averages not less than 100 feet, though there are numerous places where the rock is entered at 10 or 20 feet or less. In the southern portion of the county, where only the older drift is present, the thickness on hills and ridges seldom reaches 20 feet, but in the valleys or lowlands it is much thicker and probably in some cases exceeds 100 feet. The wells in this portion of the county usually obtain water in the rock when on the hills and ridges, but when on lowlands they obtain water in the drift.

There are a few springs along the valleys, but they seldom constitute an important water resource.

Individual wells.—At Fincastle, in the northern part of the county, wells on the low ground find no rock at 30 feet, but south from this village on the higher ground rock is struck at 20 or 30 feet. In sec. 8, T. 15, R. 4 W., a well in a valley obtains a flow at 20 feet without entering rock.

In the vicinity of Bainbridge, on an elevated ridge, several wells reach a depth of 80 feet before entering rock. Two such wells are found in the village, one at a sawmill and the other just north of the railway depot. About a mile northeast of Bainbridge, on ground probably 40 feet lower, wells enter rock at a depth of 20 feet.

Records of several wells were obtained in the southwestern part of the county on nearly plane tracts outside the limits of the later drift sheet, which enter rock at about 20 feet.

On the hills in the southern part of the county wells drilled into the rock range in depth from 20 feet or less up to fully 100 feet. There is apparently no definite horizon at which water may be obtained. In the northern portion of the county wells are seldom drilled far into the rock before obtaining water.

HENDRICKS COUNTY.

General statement.—Hendricks County is situated in the central portion of the State, immediately east of Putnam County. Its county seat, Danville, is near the geographic center. It has an area of 400 square miles. This county was entirely covered by the ice at its later as well as its earlier invasion, and has in consequence a smooth surface, with the preglacial ridges and valleys almost concealed. A moraine of moderate proportions traverses the northwestern part of the county in a northwest to southeast direction, passing just west of the city of Danville. It fades away a few miles south of Danville into a gently undulating plain, where its continuation is traceable chiefly by the belt of bowlders which is an accompaniment of the morainic belt. The breadth of this moraine is 2 to 5 miles, being widest in the vicinity of Danville. Aside from this belt, the county has a gently undulating surface.

The drift is principally a compact till, though there are small areas in which it assumes a gravelly constitution. In its deeper portions also it often contains considerable sand and gravel. There are few places in which the writer was able to distinguish the older from the newer drift in this county, and it is thought that the greater portion of the drift belongs with the later ice invasion. In the southern portion of the county rock is often struck in wells at depths of 20 to 50 feet, but in the northern portion the rock appears to be buried to a depth of 100 to 150 feet.

Individual wells.—At North Salem, in the northwestern part of the county, records of two deep wells were obtained, one 70 feet, the other

85 feet, neither of which entered rock and both were mainly through blue till. Wells in that village are often obtained at about 20 feet.

At Lizton, and also at Brownsburg, in the northern part of the county, the wells are obtained at shallow depths, seldom so much as 40 feet. In the farming districts, also, wells are obtained usually at shallow depths. The great thickness of drift in the northern part of the county has been made known by gas borings, of which there are several.

At Plainfield, in the eastern part of the county, wells are usually obtained at 35 or 40 feet, though some are of less depth. Rock is struck in the gas boring at about 90 feet.

At Danville the waterworks obtains its supply from flowing wells 110 feet in depth, which do not reach the rock. A 3-inch well is estimated to furnish about 2,000 barrels per day. There are two 3-inch wells and two 2-inch wells in use. Private wells are obtained in Danville at about 40 feet. A well at the court-house penetrates—

	Feet.
1. Yellow till	15
2. Blue till	25
3. Sand and gravel	5
Total	45

The gas borings at Danville penetrate about 160 feet of drift.

At Clayton wells are obtained at 10 to 25 feet. They are mainly through till, but some have considerable sand and gravel.

At Amo wells 40 to 50 feet in depth do not reach rock. They usually penetrate about 25 feet of yellow till. On the plain north of Amo a blue till is struck at 10 or 15 feet.

At Coatsville wells are mainly through till to a depth of 25 or 30 feet without striking rock. A well 1 mile south of this village, however, enters rock at 8 feet.

At Reno two wells enter rock at about 25 feet, but several obtain water in the drift.

A well on an elevated point about 5 miles north of Reno strikes rock at 70 feet, but a neighboring well on lower ground does not strike rock at 90 feet. There are outcrops of rock along the creek in Sec. 29, T. 16, R. 2 W., in the neighborhood of these wells.

MARION COUNTY.

General statement.—Marion County is situated just south of the center of the State, with Indianapolis, the State capital, and also the county seat, near its geographic center. It has an area of 400 square miles. White River traverses the county nearly centrally from north to south. Throughout much of its course in the county it is bordered by a broad gravel plain, averaging, perhaps, 2 miles in width, though much narrower at the northern border. This gravel plain is underlain by till, and the entire county is covered thickly with a sheet

of compact till. In a few places rock is struck at 30 to 50 feet, but throughout much of the county the drift exceeds 100 feet, and in places is about 250 feet in thickness. In the southern and southeastern part the surface is more undulatory than in the northern and western part, swells 20 or 30 feet in height being numerous, while occasional ridges reach a height of 50 or 75 feet. This undulatory drift is continued on the east in a more sharply defined morainic belt, of which mention is made in the reports on Hancock, Henry, and Randolph counties. West from White River this belt is very poorly defined, and some uncertainty is felt concerning its line of continuation.

The dug wells in this county are often obtained at a depth of 10 to 20 feet, near the junction of the yellow and blue tills, where sand beds often occur. Tubular wells are usually sunk to much greater depth, and in nearly every township several may be found which exceed 100 feet. The great majority penetrate a large amount of blue till. The water appears to be obtained in comparatively thin beds of gravel and sand associated with the till.

Individual wells.—At the city of Indianapolis, which is situated on the gravel plain bordering White River, a large amount of water may be obtained near the base of the gravel at depths of 30 to 50 feet. As there is no overlying stratum of clay contamination is liable to occur. This fact being appreciated, many tubular wells, known as Rouse wells, have been sunk to depths ranging from 60 to 90 feet, and water is obtained in gravel beneath a sheet of blue till. The city waterworks obtains about three-fourths of the supply from wells. These wells obtain water both from the surface gravel and the deeper beds. The remainder of the water supply is obtained from White River, and is filtered before it is pumped to the mains. The waterworks company have sunk a number of deep wells with a view to obtaining a larger and better supply. Rock is entered at about 80 or 85 feet. The deepest well reported has a depth of 343 feet. From these deep wells water rises a few feet above the level of the water in White River. It is hard and contains some sulphur and also considerable iron. The mineral ingredients, however, are not considered objectionable.

The thickness of drift at several points in the county and the sections of a few borings have been obtained from gas companies. The Capital City Gas Company have several wells in the northeast part of the county which penetrate 140 to 230 feet of drift, of which a large part is blue till. There are, however, beds of sand and gravel which would afford an abundant supply for water wells. In the eastern part of the county the thickness of the drift at several villages is as follows: Oakland, 231 feet; Lawrence, 188 feet; Brightwood, 190 feet; Irvington, 130 feet; Cumberland, 230 feet. At Cumberland the drift is reported to consist of till, mainly of blue color, 50 feet, followed by

alternations of till with sand or gravel, each a few feet in thickness, 180 feet.

At Indianapolis the drift usually exceeds 80 feet, and in one well near the Union Depot reaches a depth of 118 feet. This well, which is located between Pine and Delaware streets, has the following section of drift:

	Feet.
1. Sand and gravel	45
2. Gray till	15
3. Alternations of till with sand and gravel	58
Total	118

A well about a mile south of the Union Depot, on Meridian street, enters rock at 80 feet. The drift section is as follows:

	Feet.
1. Sand	10
2. Till	25
3. Gravel, a few feet.	
4. Till, several feet.	
5. Quicksand, extending to the rock.	

At the waterworks borings, referred to above, a section of one well was obtained, as follows:

	Feet.
1. Sand and gravel	45½
2. Blue till	20
3. Sand and gravel	15
4. Limestone struck at 82 feet 7 inches.	

There was continuous limestone from this depth to the bottom of the well at 343 feet.

North from Indianapolis, in the vicinity of Broad Ripple, records of 30 wells were obtained, all located in the White River Valley, which show the drift to range from 45 feet to 90 feet. It is mainly sand and gravel, though thin sheets of till occur. Two wells in the valley, near Allisonville, have 70 feet of drift, mainly blue till. At Castleton, on the uplands east of White River, the drift is 78 feet, mainly till.

A gas boring in the west part of the county, at Bridgeport, has 100 feet of drift, as follows:

	Feet.
1. Creek alluvium	8 or 10
2. Alternations of blue till with sand	30
3. Quicksand	10
4. Blue till	40
5. Gravel and sand	10
Total	100

A well near Bridgeport penetrates 280 feet of drift, but an accurate section was not obtained.

At Glen Valley, in the southern part of the county, on the border of the White River gravel plain, records of two wells were obtained which are through sand and gravel to a depth of 53 and 56 feet. Wells are usually obtained, however, at less depth.

HANCOCK COUNTY.

General statement.—Hancock County is situated in the east-central art of the State, immediately east of Marion County, with Greenfield s its county seat. It has an area of 307 square miles. Like Marion ounty, it is covered thickly with a sheet of till. The southern half as an undulatory surface, with numerous swells 20 or 30 feet in eight. The northern part has a nearly plane surface. The entire ounty has a gradual descent from east to west, the altitude at the astern border being about 1,000 feet, while at the western it is scarcely 00 feet above tide. In this county, as in Marion, dug wells may usuly be obtained at 10 to 20 feet at the junction of the yellow and blue ills. Tubular wells are usually 50 to 100 feet or more in depth.

Individual wells.—In the vicinity of Greenfield wells usually obtain good supply of water at about 30 feet below a bed of till. The waterorks wells are sunk to the rock, near the top of which they obtain ater at a depth of 176 feet. In these wells the water rises a few feet bove the surface, and an 8-inch well is estimated to furnish 150 galons per minute.

At the village of Philadelphia wells are usually obtained at about 0 feet after penetrating yellow till and a few feet of blue till.

In the vicinity of New Palestine, in the western part of the county, ells are usually obtained at 25 or 30 feet. The gas-well boring at his village penetrates 285 feet of drift.

At McCordsville, in the western part of the county, wells are usually btained at depths of 40 feet or less. The drift at this point is 186 eet, mainly till.

In the eastern part of the county wells in the villages are usually btained at about 20 feet, but on farms tubular wells are often sunk o much greater depth. Several gas-well borings in this part of the ounty penetrate about 200 feet of drift, mainly blue till.

HENRY COUNTY.

General statement.—Henry County is situated in the eastern part f the State, with Newcastle as the county seat. It has an area of 00 square miles. A moraine traverses the county from southwest to ortheast (passing west and north of the city of Newcastle), which onstitutes the divide between the West White and East White rivers. n the northeastern part of the county it is a prominent feature, with harp knolls and ridges, in some cases 50 to 75 feet or more in height, among which are winding sloughs and shallow basins. In the western nd southwestern part of the county the expression of the moraine is nore subdued. From this moraine there is a rapid descent to the orthwest; but eastward from the moraine the surface continues elated and has an altitude 1,000 to 1,100 feet above tide. On the astern border of the county there is a moraine with gently undulating

surface which constitutes the divide between the East White and the Whitewater River system. There is also a small moraine leading south from the central part of the county, along the border of Flat Rock Creek. Between these moraines there are plane tracts with slightly lower elevation than the morainic ridges. The northwest corner of the county is also a plain.

This county has, perhaps, the thickest drift to be found in the State, one well near Newcastle having penetrated 500 feet before striking rock and one at Cadiz more than 400 feet. The drift of this county, as in the counties to the west, is largely composed of a compact blue till.

Individual wells.—The general depth of wells in this county is no greater than in the counties with lower elevation on the north and west, there being usually an adequate supply of water at 20 to 40 feet. In a few places, water not being abundant, tubular wells have been sunk to depths of 100 feet and occasionally 200 feet, or even more.

At Newcastle the private wells range in depth from 12 to 50 feet, the majority being about 20 feet. The waterworks wells sunk in the valley of East White River range in depth from 90 to 250 feet and are obtained in all cases in gravel, associated with sheets of till. One of the shallower waterworks wells is reported to have the following section:

	Feet.
1. Clay	10
2. Gravel	15
3. Quicksand	25
4. Blue clay	31
5. Gravel	2
6. Hard till	7
7. Coarse gravel, with water at bottom.	
Total	90

The waterworks wells have a head about 20 feet above the surface. Analyses of the water from two of these wells are given elsewhere.[1] Gas-well borings in the vicinity of Newcastle show 300 to 500 feet of drift on the borders of the East White River Valley, but on the upland plain east of Newcastle, at an elevation of 75 feet or more above the valley, rock is struck at about 250 feet.

At Moreland, in the northeast part of the county, in the valley of Flat Rock Creek, the drift is 150 feet, largely till, but a bed of gravel at about 90 feet furnishes a flow of water.

At Mount Summit, in the northern part of the county, on an elevated part of the moraine, the drift is shown by a gas-well boring to be 235 feet, mainly sand and gravel. At Springport, on the north slope of the same moraine, the drift is 170 feet and is largely till. Two miles north of Springport rock is struck at 156 feet.

At Luray a boring for water 240 feet did not reach rock.

[1] *Eighteenth* Ann. Rept. U. S. Geol. Survey, Part IV, p. 499.

At Honeycreek station, on the plain in the northwest part of the county, the drift exceeds 200 feet, and at Sulphur Springs is about 250 feet. At Middletown, in the extreme northwest corner of the county, a boring on the upland plain, north of Fall Creek, enters rock at 203 feet. The drift is mainly sand and gravel. About 2 miles south of Middletown a gas boring penetrated more than 200 feet of drift and passed through a log near the bottom. A well in Fall Creek Valley, at Middletown, strikes rock at 160 feet. A flow of water was obtained at 82 feet. In this well also logs were penetrated at a depth of about 75 feet.

At Cadiz, on the moraine in the west-central part of the county, a gas boring penetrates 421 feet of drift. About midway between Cadiz and Newcastle, on a plain east of the moraine, the drift is 303 feet. At Greensboro, about 5 miles below Newcastle, in the East White River Valley, rock is struck at less than 200 feet, and outcrops of rock occur farther down the river in the vicinity of Knightstown. At Kennard, in the west part of the county, a gas well penetrates 247 feet of drift, consisting of alternations of till with gravel and sand.

In the village of Knightstown private wells are usually obtained at a depth of 20 to 40 feet in gravel beds below clay. The waterworks wells are obtained near the top of the limestone, at a depth of 57 and 58 feet.

At Ogden, 5 miles east of Knightstown, the drift is 154 feet, of which the upper 20 or 30 feet is sand and gravel and the remainder till.

In the vicinity of Spiceland, on a plain east of White River, the drift ranges in depth from 90 feet up to 150 feet, and is largely till.

In the vicinity of Dunreith, on the south border of the county, the drift ranges from 160 to 215 feet, the greatest depth being found in a well 1 mile northwest of the village.

At Lewisville, on the border of Flat Rock Valley, 247 feet of drift is penetrated, mainly sand and gavel.

WAYNE COUNTY.

General statement.—Wayne County is situated on the east border of the State, with Richmond as its county seat, and has an area of 380 square miles. Like the bordering counties on the north and west, its altitude is high. Its general elevation falls but little below that of Randolph County, the highest county in the State. At the north boundary, near the Randolph County line, the elevation is 1,150 to 1,200 feet or more. The northern one-third of the county probably has an average altitude of not less than 1,100 feet. There is a gradual southward descent across the county, and its south border is slightly below the 1,000-foot contour, except perhaps for a few miles near the State line.

Several drainage *lines, having* remarkably large valleys, traverse

the county in a general north to south direction, among which may be mentioned Nettle Creek, West Fork, Martindale Fork, Greens Fork, and Nolands Fork, all of which unite to form the West Whitewater. A profile across the county from west to east, in its northern part, oscillates 100 to 150 feet in crossing these valleys and the ridges which separate them. The valleys or troughs are larger than the present stream channels, for the immediate bluffs rise but a few feet above the stream beds. These troughlike valleys are cut in a sheet of old drift, over which a thin sheet of later drift has been spread, a sheet whose southern boundary is found in counties immediately south. Along the eastern part of the county the rock has a higher general elevation than in the central and western portion, and here the principal drainage line, East Whitewater, has a postglacial channel partly excavated in the rock. With the exception of the southeastern part of the county the drift deposits are generally 150 to 200 feet or more in thickness.

There are extensive gravel plains in the western part of the county, bordering the valleys of Nettle Creek, West Fork, and Martindale Creek. For a few miles above the mouth of Martindale Creek, at Cambridge City, the gravel plain occupies the entire interval between West Fork and this stream, but in the northern portion of the county the valleys are separated by a ridge of till. Narrow, gravelly belts occur also along Greens Fork and Nolands Fork, but they seldom reach a width of a mile. These gravel deposits are apparently the outwash from the ice-sheet at the time it formed the strong moraine at the headwaters of these streams in southern Randolph County. On these gravel plains wells are usually obtained at about the level of the streams, 20 to 40 feet. On the uplands between these gravel plains the drift usually consists of till, and wells are obtained at moderate depths, seldom more than 40 feet.

Individual wells.—At Hagerstown, in the northwest part of the county, flowing wells are obtained in the valley of Nettle Creek at a depth of about 80 feet. They are largely through gravel, but penetrate a bed of till just above the water vein. In eight gas borings made in the vicinity of Hagerstown, along the valley of Nettle Creek, the drift has an average depth of about 100 feet. The least distance to rock is 78 feet.

At Williamsburg, in Greens Fork Valley, in the north part of the county, wells are obtained at 18 to 25 feet, mainly in gravel. At Fountain City, in the valley of Nolands Fork, wells are obtained at similar depth. A gas boring at Fountain City penetrates 185 feet of drift.

At Richmond wells are obtained at from 12 to 40 feet. In a few instances water is obtained in the drift, but usually the wells enter the limestone. The city water supply is obtained from springs. Professor Dennis, chemist of Earlham College, reports that the waterworks supply and also water from the river is of excellent sanitary

quality, but he has found by analysis that the wells contain 10 to 30 times as much chlorine as is found in the river water above the city, and he states that more or less malaria constantly exists where wells are used.

At Centerville, near the valley of Nolands Creek, a gas-well boring penetrates 176 feet of drift, mainly blue till. Ordinary wells are obtained at 30 or 40 feet, more or less. Another gas boring is reported by Dr. Phinney to have about 250 feet of drift, with a flow of water at 246 feet.

At Cambridge City, in the valley of West Whitewater River, wells are usually obtained in gravel at 15 to 25 feet. Two gas-well borings at this city enter rock at about 100 feet. After passing through 15 or 20 feet of gravel the drift is mainly blue till.

On the uplands east of the West Whitewater, in the southern part of the county, water wells in some cases reach a depth of 80 feet without striking rock. On the uplands west of this stream, gas-well borings have shown the drift to have a thickness of 150 to 300 feet, the greatest thickness noted being found in the village of Dublin. There are, however, outcrops of rock along the Whitewater, in the vicinity of Cambridge City, showing that the rock surface has a variation of fully 200 feet within 1 or 2 miles of that city.

On a plain south of Richmond, in the southeast corner of the county, wells have, in some instances, been sunk to a depth of 60 feet through till without entering rock. As a rule, however, rock is found in that part of the county at 50 feet or less, and over quite extensive areas it has outcrops nearly as high as the bordering upland.

Dr. Phinney reports the drift in a gas boring at Dalton, in the northeast corner of the county, to be 275 feet and at Walnut Level, in the western part, 280 feet. At Washington, near the center of the county, it is 212 feet.

UNION COUNTY.

General statement.—Union County is situated on the east border of the State, between Wayne and Franklin counties, with Liberty as its county seat, and has an area of 170 square miles. Its western part is traversed from north to south by the East Whitewater, which occupies a rather broad valley 100 feet or more below the adjacent upland on the east and west. The eastern part of the county is nearly plane. The drift filling is sufficient to give a smooth surface to what would otherwise be a hilly district. Although rock is often struck at depths of 20 to 40 feet where ridges or preglacial uplands occur, it is apparently buried to a depth of 200 feet or more in the larger valleys. The greater part of the drift is a compact till, but wells are usually obtained at convenient depths in beds of sand or gravel associated with it. They rarely exceed a depth of 50 feet and are usually less than 25 feet.

Individual wells.—A few tubular wells in the eastern part of the county reach depths of 50 to 90 feet and penetrate—

	Feet.
1. Yellow till	10 to 12
2. Blue till	40 to 80

At Bechy Mire, in the northeast part of the county, a well at Mr. Lybrook's is reported to have entered a hard yellow till below a soft blue till at a depth of 33 feet. A well 3 miles southeast of Liberty enters a hard yellow till below soft blue till at a depth of 35 feet. A well at the Pyle House, in Liberty, passes through a bed of swamp muck, with leaves below blue till at a depth of 35 feet. Beneath the muck, sand was penetrated, in which water was obtained at 52 feet. At Joseph Coffman's, 2 miles south of Brownsville, a well passes through a bed of swamp muck below gravelly drift at 20 or 30 feet. It seems probable that the swamp muck and the hard yellow till, found in the four wells just mentioned, pertains to a drift sheet much older than the overlying drift.

At Liberty water is usually obtained at 30 to 45 feet in sand and gravel below till. At the waterworks a supply is obtained at a depth of 21 feet in sand below clay. A partial analysis shows the presence of chlorine in sufficient amount to indicate that the water may be contaminated, and suggests the advisability of obtaining water from a better source. The drift at Liberty is 60 to 90 feet in depth and is underlain by a limestone which is likely to yield an abundance of water at convenient depths.

There is a flowing well about 3 miles southeast of Liberty, on Mr. Bratton's farm, 42 feet in depth, from sand below till.

In the extreme southeast part of the county rock is struck at 5 to 20 feet. Wells in the vicinity of Lotus, 35 or 40 feet deep, do not enter rock; they are mainly through till.

FAYETTE COUNTY.

General statement.—Fayette County is situated in the eastern part of the State, with Connersville as its county seat. It has an area of 210 square miles. It is traversed nearly centrally from north to south by the broad valley of the West Whitewater River, which carries a gravel plain 1 to 2 miles in width. At the later ice invasion there was a reentrant angle in the ice sheet in southeastern Indiana which had its northernmost point in the Whitewater Valley, in southern Fayette County. The boundary at this later invasion is marked by a well-defined though not bulky morainic ridge. The ridge formed on the western side of the reentrant angle enters Fayette County from southeastern Rush and northwestern Franklin counties and passes northward, coming to the Whitewater Valley about 4 miles below Connersville. Here it meets the ridge formed on the east side of the reentrant angle, and from that point northward an interlobate moraine

was formed which extends northward into Wayne and Henry counties. Through the midst of this interlobate moraine the Whitewater River has its passage. On either side of the Whitewater, in the south part of the county, there is a small district in which the newer drift is absent, and a coating of white clay or silt several feet in thickness covers the till of the earlier invasion. Here, as has been noted in other counties of Indiana, the older drift sheet is much more highly oxidized and harder than the newer sheet. In the newer drift wells may be easily spaded or bored, while in the older drift a pick or drill must often be used.

Rock is seldom encountered on the uplands of this county at less than 50 feet, and there appears to be generally 100 feet or more of drift. The drift consists mainly of a compact till, though wells are usually obtained in sand or gravel associated with the till at depths of 35 feet or less.

Individual wells.—At Connersville the water vein is found in gravel at a depth of about 30 feet near the level of the Whitewater River. Below this depth till is often found under which there is a water-bearing gravel at a depth of 60 to 80 feet from the surface. There appears to be danger of contamination in the shallower wells, but the deeper wells are thought to be free from such contamination. The city waterworks obtain the supply from the Whitewater River, but the domestic use is mainly from wells.

A few records of farm wells were obtained both on the east and west of the Whitewater Valley. The deepest one, near Alquina, is only 43 feet, the others range from 30 feet down to 20 feet. In nearly all the wells till constitutes the main part of the section. It is probable that those located on the newer drift are not sufficiently deep to reach the older sheet of till.

RUSH COUNTY.

General statement.—Rush County is situated in the eastern part of the State, with Rushville as its county seat, and it has an area of 414 square miles. It has a nearly plane surface, though a small moraine crosses its southeast corner and another one traverses its western half from north to south, following the west border of Flat Rock Creek. There is a general southwestward descent, the altitude in the northeast corner being nearly 1,100 feet, while the southwest corner falls below 900 feet. The drift is composed mainly of till, though the lower part is frequently sand and apparently has an average thickness of fully 100 feet. The county has been covered entirely by the later ice invasion as well as by the earlier one. The extreme limits of the later invasion are, however, just outside the southeastern border of the county, at the moraine above noted. Along Flat Rock Creek, in the northern part of the county, there is a gravel plain covering several *square miles,* which lies immediately outside and

southeast of the moraine referred to above, and is, in all probability, an outwash from it. There is also a gravel plain along East White River, in the northwest part of the county, probably formed from the moraine situated on its west border.

Individual wells.—In the vicinity of Raleigh, on the gravel plain in the north part of the county, several flowing wells have been obtained at depths ranging from 65 to 106 feet. They have a head 3 to 6 feet above the surface. The water is obtained from gravel below a sheet of till, but the wells penetrate a large amount of surface gravel before entering the till.

Along the moraine in the northern part of the county and on the plain west of it wells usually enter sand below till at 12 to 25 feet. In some cases the wells have been sunk some distance into sand before obtaining water. At Hamilton Station one well penetrates 92 feet of sand.

Near Carthage, in the northwestern part of the county, on the gravel plain along East White River, rock is sometimes struck at a depth of 50 feet, and the drift is mainly gravel. At Arlington, in the western part, wells are usually obtained in sand below till at a depth of 20 to 30 feet.

At Homer the drift is mainly sand after penetrating a few feet of surface till, and water is obtained at 20 feet or less. The gas well enters rock at 53 feet.

A gas well 7 miles north of Rushville penetrates 147 feet of drift—mainly sand, 92 feet; blue till, 55 feet.

At Rushville a gas well near the school building penetrated 60 feet of drift, mainly till. Water wells at Rushville are obtained at depths ranging from 14 to 75 feet. Several flowing wells have been obtained from the drift in and near the city along the valley of Flat Rock Creek. They are strongly chalybeate and also sulphurous.

At Glenwood, near the eastern border of the county, a gas well penetrates 120 feet of drift, of which the upper 60 or 70 feet is till and the remainder sand and gravel. Wells are obtained in the vicinity of that village at depths of 20 feet or less, though an occasional tubular well is sunk to the underlying heavy bed of sand.

At New Salem, in the southeastern part of the county, wells are obtained in sand below till at 40 or 50 feet.

Along the morainic ridge in the extreme southeastern part wells in some cases are sunk to a depth of 60 feet, mainly through till.

Along the southern border rock ledges appear in the bluffs of streams at 20 to 40 feet below the level of the bordering uplands, but wells usually obtain water without entering the rock.

SHELBY COUNTY.

eral statement.—Shelby County is situated southeast of the of the State, with Shelbyville as its county seat, and has an f 400 square miles. The eastern part is more elevated than estern, but has a generally plane surface, the only morainic pment being a small ridge in the southeast corner. The n part has a more diversified surface, produced in part by nic ridges and in part by channels which were formed apparprior to the deposition of the moraines and their associated outwash, and which have been in part filled by the outwash he moraines. The eleventh annual report of the State geolontains a map which outlines the distribution of the several els. The map is somewhat misleading in that it represents land-like areas between these channels to be highland. The le is, in fact, only a few feet above the channels, seldom than 25 feet, except in the case of a morainic ridge in the southpart of the county, which has points standing fully 100 feet the bordering channel. The full interpretation of the drainage y of this region has not been made, but it seems probable that lerable erosion of the drift plain had occurred during a retreat ice and that subsequently the ice invaded the western half of unty, blocking up portions of the channels, either by morainic ulations or an outwash of gravel from the ice margin. In the ty of Fairland and to the northeast from that village the moraine ates into a gravelly plain on its east border, and this gravelly slopes downward into one of the channels represented on the ccompanying the Indiana report. Well sections are given below, show the amount of filling these channels have received by this sh from the ice sheet. The morainic features on the west r of the county are of a strong type only in the southwest townwhere the ice margin appears to have made an abrupt curve to est. The sharp moraine was apparently formed because of this ike projection of the ice sheet.

drift of the uplands in the eastern part of the county is comlargely of till and has a depth of 50 feet or more, if we may from outcrops of rock and occasional gas borings. The water are usually obtained without entering rock, there being beds of or gravel associated with the till. In the western part there rs to have been a preglacial basin with a rock surface much than that of the eastern portion of the county. This has been to a depth of perhaps 150 feet by the drift deposits, and the cial reliefs thus greatly obscured. The well sections given will serve to illustrate the variability of the drift structure.

ividual wells.—Gas wells in the northwestern part of the county rate 150 to 200 feet of drift, of which the greater part is till.

The water wells of that region are usually obtained at depths of 15 to 50 feet, but occasionally reach a depth of 100 feet.

Wells on the gravel plain along East White River, above Shelbyville, have in several instances reached the bottom of the gravel and entered till at a depth of 25 or 30 feet.

The gravel plain along Brandywine Creek, east and northeast from Fairland, carries about 30 feet of gravel, beneath which is a sheet of till.

In Fairland the wells in the north part of the village penetrate 15 to 25 feet of till, at which depths they enter a water-bearing gravel. The southeast part of the village extends into the gravel plain, and wells there are obtained at similar depths without penetrating till.

Along Big Sugar Creek, west and southwest from Fairland, wells sometimes penetrate 50 or 60 feet of gravel without encountering till.

In an abandoned valley leading southward from East White River at Shelbyville to Lewis Creek and thence to Flat Rock, a valley which is generally termed the Slough, the gravel is 35 feet or more in depth and is underlain by till.

Along Flat Rock Creek, in the southern part of the county, wells are usually obtained at 10 to 20 feet.

On a morainic ridge near Mount Auburn, on J. M. Collins's farm, a well 108 feet in depth had the following section:

	Feet.
1. Sandy yellow till	20
2. Blue till	80
3. Sand and gravel	[illegible]
Total	10[illegible]

Two other wells near Mount Auburn enter rock at 50 feet. On [illegible] plain north of Mount Auburn, known as "The Flat," in sections [illegible] and 9, Jackson Township, till is entered below gravel at a depth of 1[illegible] or 15 feet, and wells are in some cases obtained at 30 feet.

The following well sections of drift near Manilla are obtained from the eleventh report of the State geologist. Jacob Henry's well penetrates—

	Feet.
1. Soil	[illegible]
2. Loamy yellow clay	[illegible]
3. Loamy sand	1[illegible]
4. Bowlder clay, blue	4[illegible]
5. Fine quicksand	3
6. White sand	1
7. Gravel and sand	2
Total	73

The water rises within 1 foot of the surface.

On the adjoining farm of Arbuckle & Mills a well reaches a depth of 122 feet, penetrating—

	Feet.
1. Soil	2
2. Clay	33
3. Quicksand	3
4. Blue clay	5
5. Clay and gravel	2
6. Bowlder clay	17
7. Sand and gravel	3
8. Blue bowlder clay	57
Total	122

From the same report the following section of the boring on the farm of J. M. Collins, given above in somewhat different form, is obtained:

	Feet.
1. Soil	4
2. Yellow clay	6
3. Sandy clay	10
4. Bowlder clay	80
5. White sand	1
6. Sand and gravel	7
7. Limestone at bottom.	
Total	108

The bottom is estimated to be 50 feet below river level.

At Waldron, in the southeast part of the county, the drift is in places 80 feet in thickness, as shown by gas borings. A water well in the village is reported to have entered rock at 53 feet. It penetrates—

	Feet.
1. Yellow till	10
2. Sand and gravel	14
3. Gray till	28
4. Sand	1
5. Rock, thought to be sandstone	3
Total	56

At St. Paul the drift varies from 15 feet or less to nearly 100 feet in depth. The following depths are reported in gas-well borings: In No. 1, 17 feet; in No. 2, 87 feet; in No. 3, rock at surface; in No. 4, 16 feet; in No. 5, 23 feet. Water wells range in depth from 15 to 90 feet.

At Cynthi Ann, in the east part of the county, wells are usually obtained at 10 or 12 feet on level tracts, but on drift knolls in the village they reach a depth of 25 or 30 feet, and are mainly through till.

In the portion of the county northeast from Shelbyville wells range in depth from 10 to 50 feet or more, and are mainly through till.

Mention is made in the eleventh report of the State geologist of two wells in this county having water of exceptionally high temperature.

One in the east part of Shelbyville, 24 feet in depth, is reported to maintain a constant temperature, winter and summer, of 76° F. The other well, located 4 miles west of Shelbyville, is said to have increased in temperature after it was made, the water becoming too warm for drinking purposes, its temperature having reached 65° F. A pipe was driven in the bottom of the well to a depth of 16 feet, or 39 feet from the surface. The water was then found to have a temperature of 80°, and during that winter increased to 86° F. As these wells were excavated for potable water only, they have been filled.

JOHNSON COUNTY.

General statement.—Johnson County is situated in the south-central part of the State, with Franklin as its county seat, and has an area of 320 square miles. The greater part of the surface is plane, but there are morainic ridges of moderate strength traversing the county. One, which crosses the northern tier of townships from west to east, is known as the Greenwood moraine, the village of Greenwood being situated upon it. It is a belt but 1 to 2 miles in width, and has a relief of only 25 to 50 feet above bordering plane tracts. Another belt leads diagonally across the county from its northwest to its southeast corner, passing west and south of the city of Franklin. This moraine has a width of 2 to 5 miles, and varies greatly in strength. It is, on the whole, a less definite ridge than the one in the north part of the county. It has, however, numerous sharp knolls rising 25 to 40 feet, and occasionally 60 feet, above border tracts. From this morainic belt a small one leads off to the east just south of Franklin. It is scarcely a mile in average width, and has a relief of 20 to 40 feet. There is another moraine on the south border of the county, which is low and inconspicuous in the eastern part, but in the western part becomes a prominent, sharp ridge, with a relief of about 75 feet. This ridge, it is thought, belongs to the earlier ice invasion. The other moraines were formed during the later ice invasion. The southwestern part of the county appears to lie outside the limits of the later invasion.

The drift consists largely of a compact blue till, though the sharpest knolls are usually gravelly. There are gravelly plains in the southeastern part of the county, bordering the East White River, which are intimately associated with the morainic tract of that region as an outwash. In some cases deep wells have shown a large amount of sand or gravel in the lower part of the drift. The thickness of the drift probably averages 200 feet. A basin of Devonian shale which occupied the eastern and northern part of the county has been filled about to the level of the bordering rim on the southwest. The drift of the southwest part of the county is thinner than in the remainder, and wells occasionally enter the rock at depths of 20 to 60 feet. In the remainder of the county wells very rarely reach the rock. Water

s usually obtained at 40 feet or less in the dug wells and 40 to 100 feet in the tubular wells in beds of sand or gravel associated with the hills.

Individual wells.—At Greenwood, in the northern part of the county, the dug wells have a depth of but 12 to 30 feet. Tubular wells range in depth from 30 feet up to 100 feet or more. The best supply of water is obtained at 20 to 60 feet. A well at the Greenwood Sanitarium, 60 feet in depth, has sufficient head to bring the water nearly to the surface. Two wells at the fruit cannery have depths of 85 and 108 feet. The supply is from gravel a few feet in thickness in each well, but is inexhaustible. The village is making arrangements for waterworks supply from wells of this class. The Greenwood Sanitarium uses the water from two gas-well borings. The drift in these borings is 210 feet, and is largely till.

At Franklin the city water supply is obtained from driven wells 40 to 60 feet in depth. There is a small amount of surface gravel, but they are mainly through till. There are a few shallow wells 10 to 20 feet in depth obtained above the till. A well at the court-house is 80 feet, and several other wells in the city are 100 to 115 feet. Several flowing wells have been obtained in the north part of the city, on a tributary of Youngs Creek, at a depth of 40 to 45 feet. At the railway water tank in Hurricane Creek Valley a well obtains a flow of water at 30 feet. One flowing well in the southern part of the city is 90 feet in depth. Some of these wells cease to flow in dry weather. A gas-well boring in Franklin, 1,140 feet in depth, penetrates 170 feet of drift, as follows:

	Feet.
1. Till, yellow and blue	45
2. Sand	20
3. Blue till, with thin sand and gravel beds	105
Total	170

There is much water at 90 feet. There was also a flow of water from limestone at 205 to 210 feet. A well at the Baptist College, 114 feet in depth, penetrates—

	Feet.
1. Sand and gravel	18
2. Blue till	40
3. Fine sand	3
4. Blue till	50
5. Gravel	3
Total	114

Wells along the drift ridge south and east from Franklin usually penetrate 40 feet of till, beneath which water is obtained at a depth of 50 to 60 feet.

In the vicinity of Union Village wells are obtained at 30 to 75 feet in gravel beneath blue *till.*

A well on the slope of Donnell Mound, near Franklin, 40 feet above base, is mainly through gravel and sand to a depth of 50 feet.

A well at a schoolhouse in sec. 7, T. 12, R. 3 E., 95 feet in depth, penetrates 60 feet of drift, mainly till, beneath which is shale.

A well at Mr. Collins's, sec. 15, T. 13, R. 3 E., enters rock at 20 feet. A well at Mr. Wilkes's, section 14, in the same township, 40 feet in depth, does not reach rock.

At Williamsburg wells 20 to 50 feet in depth are mainly through blue till.

Wells in sec. 29, T. 11, R. 4 E., 20 to 40 feet in depth strike no rock. Wells in secs. 33 and 34, T. 11, R. 3 E., enter sandstone below till at about 20 feet.

Near Nineveh, in the southwest corner of the county, wells are 25 feet or more in depth, mainly in yellow till.

At Edinburg, in the southeast corner, wells are obtained at 25 to 60 feet, the usual depth being 30 to 40 feet. They are mainly through gravel; the city waterworks are supplied from such wells. At a gas boring in Edinburg 115 feet of drift was penetrated; the boring is 1,580 feet in depth. The salt water struck near the bottom rises within 80 feet of the surface.

MORGAN COUNTY.

General statement.—Morgan County is situated in the west-central portion of the State, with Martinsville as its county seat, and has an area of 430 square miles. Along the eastern and northern borders of the county the drift is heavy and the surface plane or but slightly hilly. In the central, southern, and western portions the surface is hilly and broken and the drift deposits thin. White River traverses this hilly district in a valley 1½ to 2 miles in width and 150 to 200 feet in depth. Its broad valley is filled with drift deposits to a depth of about 100 feet. Indian Creek, an eastern tributary entering near Martinsville, also has a broad valley deeply filled with drift.

The northern part of the county was covered by the ice at its later invasion, but the remainder appears to have been covered only at the earlier invasion. The glacial boundary is but a few miles south of the county limits, in northern Brown and northern Monroe counties. A prominent morainic ridge is found in this older drift, leading from Martinsville southeastward past Morgantown into Johnson County. Its relief in places is 75 to 100 feet, and being scarcely a mile in width, it is a conspicuous feature. This ridge, together with the remainder of the earlier drift sheet, is covered by a pebbleless clay or silt several feet in depth, which passes under the later sheet of drift. That sheet has till and bowlders at its surface.

On the elevated portions of the county there is seldom sufficient drift to afford water for wells. They are, therefore, sunk into the rock, and the depth varies considerably even in neighboring wells. Some are obtained at but 20 or 30 feet, while others are sunk to a

pth of 75 to 100 feet or more. On the lower parts of the county and ɔng the valleys, the drift being heavy, wells are usually obtained thout entering the rock, at moderate depths, seldom more than 40 et. Occasional tubular wells, however, are sunk to depths of 75 to 0 feet or more.

Individual wells.—In the northwest part of the county there is a ry level tract, known as "The Lake," which borders Mill Creek alley, and extends eastward nearly to Monrovia. Wells on this plain e 10 to 30 feet in depth. They usually penetrate a few feet of sand the top and beneath this a sheet of till before entering the water-aring sand. Wood is sometimes found at the junction of the sand th the till.

At Monrovia wells usually obtain water at a depth of about 20 feet, sand below till. One well, however, at David Miller's, near the iblic school building, is 118 feet in depth, mainly blue till. Wells ı the border of the uplands, south and southwest of Monrovia, occa-ɔnally obtain water at 20 to 30 feet without entering rock. The ajority, however, are sunk a short distance into the rock.

Wells on the morainic ridge east and southeast from Martinsville e in some cases 50 feet in depth. Some wells are largely through nd and gravel, others almost entirely through till.

At Morgantown, on the slope of the ridge, wells penetrate a surface ay and yellow till to a depth of 18 or 20 feet, beneath which there often a blue till, though in some cases wells immediately enter a ater-bearing gravel. Their depth ranges from 25 feet to 50 feet. ells are obtained in drift for about 3 miles south from this village depths of 30 feet or less.

In Martinsville the wells are usually dug to a depth of 20 or 30 feet ırough gravel. The city water supply is from a large well 30 feet in ɔpth and 30 feet in diameter. There are a few flowing wells obtained the northeast part of the city at depths of 40 to 75 feet. They pene-ate a sheet of till below the surface sand and gravel. Several deep tesian wells have been sunk at this city, which furnish a soft sul-ıur water, which has a high reputation. Sanitariums have been ıilt to accommodate the invalids who resort to these wells. Statistics ɔncerning the wells and the character of the water are discussed sewhere.[1]

OWEN COUNTY.

General statement.—Owen County is situated in the west-central ırt of the State, with Spencer as its county seat, and has an area of 0 square miles. The entire surface is hilly. In its eastern portion ıe hills are of limestone and in its western of sandstone. White iver traverses its southeastern part in a valley very much narrower ıan the portion immediately above in Morgan County, the width ɔing seldom so great as one-half mile. The highest parts of the

[1] *Eighteenth Ann. Rept. U. S. Geol. Survey*, Part IV, pp. 490-491, 498, 541.

uplands stand about 300 feet above the valley, but the immediate bluffs rise only 100 to 150 feet. The stream is in places in a new course and has its bed upon the rock, while in other places it is flowing on a drift filling 100 feet in depth. The drift deposits vary greatly in thickness, there being on many of the hills scarcely a trace of drift, while in one valley it has a known thickness of 250 feet. This county lies outside the limits of the later ice invasion, but it was almost entirely covered by the earlier invasion. Possibly the extreme southeast corner has escaped glaciation. The drift is variable in structure, some of the heaviest deposits being made up largely of gravel and sand, while neighboring localities are covered with an unmodified till. But little attention was given the depth of wells in this county, except at the three principal towns, Spencer, Gosport, and Quincy.

Individual wells.—At Spencer, the county seat, wells are obtained at various depths, ranging from 25 to 80 feet, with an average of perhaps 40 feet, at which depth they reach the level of the water in White River. Three artesian wells have been sunk at this city, descriptions of which, together with a water analysis, are presented in another report.[1] The drift at these wells is 90 to 97 feet in thickness.

Gosport is situated on the bluff of White River, and obtains wells at depths of 25 to 100 feet or more. Wells being difficult to obtain in some parts of the village, cistern water is substituted. An artesian well has been sunk in the valley to a depth of 926 feet, and obtains sulphur water similar to that at the neighboring cities of Martinsville and Spencer. No use is as yet made of the water, except by a few of the residents who prefer it to the hard water of the shallow wells.

The village of Quincy is situated in a lowland, probably an abandoned valley. The wells are 20 to 30 feet in depth, largely through a sandy drift. The water is said to stand within 5 to 10 feet of the surface.

Many springs are found along the bluffs in this county, which are utilized quite extensively by residents, and also resorted to by the stock.

CLAY COUNTY.

General statement.—Clay County is situated in the western part of the State, with Brazil as its county seat. Its area is 360 square miles. The greater part has a nearly plane surface, but the extreme eastern portion is hilly. The plane portion is underlain by the Coal Measures shales and soft sandstone, while the hilly portion is underlain by a hard sandstone. The drift is generally thin, rock being entered at the majority of the coal shafts within 20 feet of the surface. In the northern part of the county, however, the thickness is greater. There is probably also a deep filling along the valley of Eel River and also in other valleys. The drift is, in the main, a compact till, and in much of the county does not afford an adequate water supply. Wells

[1] *Eighteenth Ann. Rept.* U. S. Geol. Survey, Part IV, pp. 492, 499.

are therefore frequently drilled into the underlying Coal Measures strata, where an abundant supply is usually obtained at moderate depth—50 feet or less. There is a white clay or silt several feet thick covering the till throughout the county.

Individual wells.—At Perth, in the northern part of the county, wells are obtained in sandy beds between the yellow and blue till at a depth of about 15 feet. A boring for coal at this village penetrates 65 feet of drift, of which the lower 50 feet is till. A boring near this village in section 3 penetrates—

	Feet.
1. Surface clay	7
2. Sand and clay	8
3. Hard blue till	37
4. Sand and clay	11
5. Yellow till	4
Total	67

In a boring 80 rods north from the preceding the drift is 48 feet and consists of till, with the exception of 7 feet of sand at 30 to 37 feet.

At Carbon the drift is mainly till, and rock is usually struck at about 30 to 35 feet.

At Lena wells are usually 20 or 30 feet, mainly a hard blue till, and rock is not struck. A coal boring 1 mile west of Lena enters rock at 60 feet.

At Harmony the drift is about 30 feet in thickness, and wells are obtained near its base or in the upper part of the rock. At a coal shift between Knightsville and Harmony the drift is 60 feet in thickness.

At Knightsville the drift ranges in thickness from 12 feet up to about 50 feet. Wells are often obtained here at 12 to 20 feet in a sand below the surface clay.

At Brazil, the county seat, wells are usually obtained at about 20 feet, though they range in depth from 15 to 50 feet. The city waterworks are supplied from 8 driven wells, 20 feet in depth, the water being in a gravel beneath the surface clay. It is estimated that each well will yield 5,000 barrels per day. Rock is frequently struck in the vicinity of Brazil at about 20 feet, though there are several borings which penetrate 60 to 80 feet of drift. As a rule, the drift is a compact till.

In the central portion of the county the villages Asherville, Prairie City, and Saline City, obtain water in the upper part of the rock, the drift deposits being very thin, often less than 10 feet in depth. At Cory, in the west part of the county, the drift is about 40 feet, and wells are obtained without entering the rock.

At Bowling Green, in the eastern part of the county, wells enter a sandstone immediately below the soil and obtain water at various depths from 20 feet or less up to 60 feet or more.

In the southern part of the county, in the vicinity of Clay City, rock is usually entered at less than 20 feet and the majority of the wells obtain water near the surface of the rock.

VIGO COUNTY.

General statement.—Vigo County is situated on the west borde the State, with the city of Terre Haute as its county seat. It has area of 410 square miles. The broad valley of the Wabash traver its northwest part. This is bordered by a gravelly terrace nearl miles in average width. West from the Wabash is a morainic b the continuation of the Shelbyville moraine of Illinois. This oc pies perhaps half the upland on that side the river, and consist a gently undulating or subdued morainic topography, with occasio sharp knolls 30 to 40 feet in height. The bordering uplands hav very plane surface. The moraine and the plain on the north within the limits of the Wisconsin or later drift, the moraine be the terminus of that drift. The uplands east of the Wabash are pl and are covered by the older drift sheet. This drift sheet is cap by a deposit of white clay several feet in thickness. On the immedi bluff of the Wabash, and in the northeastern part of the county, th are sand dunes, probably drifted by wind from the Wabash Valle

The uplands west of the Wabash have drift varying in thickn from 10 feet or less up to more than 100 feet. The drift on the upla east from the Wabash is generally but 20 to 40 feet in depth. I probable, however, that tributaries of the Wabash, now obscured the drift, have a filling of more than 200 feet. In the Wabash V ley borings at Terre Haute show a thickness of 150 feet of drift, t rock floor being nearly 100 feet below the bed of the present strea Wells are usually obtained in the drift at depths of 20 to 40 feet less, there being very few deep wells in the county.

Individual wells.—In the sand-covered tracts in the northeast p of the county coal shafts penetrate from 5 to 30 feet of sand, bene which they are mainly through till to depths of 75 or 100 feet, wh rock is entered. Wells are obtained either near the base of the sa or in beds of sand or gravel associated with the till. One well Fontanet, 54 feet in depth, penetrates—

	F
1. Sand	
2. Clay and till	
Total	

A coal shaft 1 mile north of Fontanet penetrates 90 feet of dri as follows:

	F
1. Sand	
2. Till	
3. Sand	
4. Till	
5. Sand	
Total	

Another shaft near Fontanet, in section 12, has a similar secti

except that the lower sand bed is wanting. A third shaft in that vicinity penetrates 72 feet of drift, of which the upper 30 feet is sand and the remainder a solid bed of till. A shaft in the extreme northeast corner of the county, on Mr. Southard's land, penetrates 72 feet of drift, as follows:

	Feet.
1. Surface sand	20
2. Till	44
3. Sand	8
Total	72

At Terre Haute the use of private wells is considered unsafe and has been largely discontinued. Water may be obtained at about the level of the river at 30 to 50 feet, but there is no clay bed or impervious stratum of sufficient thickness to prevent contamination. The public water supply is obtained from the Wabash River above the city. Sanitary analyses of the hydrant water, and also of water from several private wells, are presented in another report.[1] The analyses show that a part of the water in each of the wells has been contaminated with organic matter.

Several borings for oil have been made within the limits of the city of Terre Haute which penetrate 100 to 150 feet of drift. In all these wells sand and gravel appear to extend from the surface to the bottom of the drift. These borings are discussed at some length in the Twenty-first Annual Report of the Indiana Survey.

A well near the brow of the Wabash bluff, south of Terre Haute, in sec. 32, T. 11, R. 9 W., penetrated the following interesting series:

	Feet.
1. Surface clay	5
2. Yellow sand	3
3. Fossiliferous loess	4
4. Soil and sandy peat	3
5. Bluish sandy subsoil	5
6. Yellow till	3
Total	23

A similar section was observed in the road grading immediately east of Terre Haute, at the east bluff of the Wabash.

A well in the upland, in sec. 20, T. 12, R. 8 W., strikes rock at 21 feet, and a shaft in the same section enters rock at 15 feet.

A well in sec. 32, T. 10, R. 9 W., enters sandstone at 22 feet, after penetrating the following beds:

	Feet.
1. Brown surface clay	5
2. Loess	2
3. Black soil	1
4. Brown till	14
Total	22

[1] *Eighteenth Ann. Rept. U. S. Geol. Survey*, Part IV, pp. 543-544.

Mr. Kester's well, sec. 20, T. 11, R. 9 W., penetrates 70 feet of drift mainly till. A well in section 21 of the same township is mainly through sand and gravel to a depth of 63 feet and does not reach rock.

Wells on parts of the Wabash terrace, in the south part of the county, enter rock within a few feet, but the greater part of the terrace is underlain by a heavy bed of gravel and sand.

FRANKLIN COUNTY.

General statement.—Franklin County is situated on the east border of the State, near its southeast corner, with Brookville as the county seat. It has an area of 400 square miles. This county is traversed nearly centrally by the West and main Whitewater river and its northern portion is crossed by the east Whitewater, the junction of the East and West Forks being at Brookville. These valleys are 300 to 400 below the level of the bordering uplands; and yet gas well borings in the vicinity of Brookville and Cedar Grove show a filling of 100 to 180 feet beneath the level of the present stream bed. Notwithstanding the great elevation of the uplands, the surface is plane over wide areas and the valleys are narrow. The northeastern part of the county lies within the limits of the later ice invasion. This invasion also touched the extreme northwest corner of the county. A small moraine was formed along the south border of the later sheet of drift, which, though only 30 or 40 feet in height, is readily traced, the bordering tracts being very plane as well as slightly lower. The moraine carries a few sharp gravelly knolls, but as a rule its surface is gently undulating. The older sheet of drift is covered with a deposit of white clay several feet in thickness, as in counties farther west and south, and the older drift here, as in other counties, is harder and more deeply oxidized than the newer drift.

The thickness of drift on the high uplands is often 10 feet or less, even within the limits of the later ice invasion. But it is probable that great amounts of drift are to be found in filled-up tributaries of the Whitewater system. Where rock is not entered within 10 or 15 feet of the surface the wells are usually obtained in the drift. This fact, together with the absence of gas-well borings or other prospect borings outside the limits of the Whitewater Valley, renders data concerning the thickness of drift rather meager.

Individual wells.—The city of Brookville obtains the supply for waterworks from two large open wells sunk in gravel, within 30 feet of the river channel, just above the city. The wells are sunk 12 feet below the lowest water in the river. They are excavated partly in sand and partly in rock, but the source of supply is by infiltration from the river. There are many cisterns and a few wells, both dug and driven, in use by the citizens of Brookville. The wells are sunk slightly below the level of the low-water stage in the river, a depth varying from 20 feet to 110 feet, according to elevation.

A boring at the brickyards in the south part of the city shows the ancient channel of the river to be about 180 feet below low water, or 440 feet above tide. Several other borings in the valley in the vicinity of Brookville enter rock at less depth. One near the junction of East and West Whitewater rivers penetrates 135 feet of drift, entering rock at about 495 feet above tide. Kimball's well, in Brookville, penetrates 160 feet of drift, but the rock surface here is no lower than at the well just mentioned. Bracken's well, in East Whitewater Valley, also enters rock at about the same level, after penetrating 135 feet of drift. A well at the poor farm enters rock at a similar elevation. A gas boring, 2 miles above Cedar Grove, penetrates 154 feet of drift and enters rock at about 450 feet above tide.

Wells at Fairfield, near East Whitewater, in the northern part of the county, in some instances reach a depth of 50 feet without entering rock, mainly through sand and gravel. Wells on the uplands between Fairfield and Laurel are usually obtained at about 20 feet. In the portion of the county east of East Whitewater rock is frequently entered at 10 to 20 feet, though a depth of 60 feet is occasionally reached without penetrating rock. Several sections were obtained on the plain between Little and Big Cedar creeks, east from Brookville, in which rock was entered at 8 to 20 feet.

At New Trenton, in the Whitewater Valley, wells on a terrace standing 80 or 90 feet above the river obtain water at about 90 feet. They are mainly through gravel.

At Metamora, in the West Whitewater Valley, wells are sunk about to river level, a depth of 30 feet.

Wells at Peppertown, on elevated upland, usually obtain water in sand below till at 20 or 25 feet.

Wells near Oldenburg enter rock at 40 feet or less, but water is sometimes found above the rock.

Several wells in Enochsburg strike rock at 20 feet or less, but water is obtained without penetrating far into the rock.

DECATUR COUNTY.

General statement.—Decatur County is situated in the southeastern part of the State, with Greensburg as the county seat. It has an area of 380 square miles. The county slopes gradually from northeast to southwest and drains mainly to the East White River. A narrow strip on the east border drains to Whitewater and to Laughery Creek. All except the eastern part of the county lies within the limits of the Wisconsin or later ice invasion, and a well-defined, though not conspicuous, moraine marks the limits of the drift of that invasion. It traverses the county from the northeast to the southwest corner, passing Greensburg on the east at McCoy Station. The extreme northwest corner of the county is also crossed by a moraine running parallel with the outer belt. These belts are each 2 or 3 miles or more in width, but

rise only 25 to 40 feet above the bordering plain and have a subdued expression. The sheet of older drift lying outside the limits of the newer drift may also be traced beneath the newer drift, numerous exposures of it being found along the streams in the vicinity of Greensburg. It is separated from the upper drift by both a soil and a pebbleless white clay such as covers the drift outside the moraine.

The thickness of the drift in this county is, as a rule, less than 50 feet, and at many places wells enter rock at 20 feet or less. The streams also are bordered quite extensively by rocky bluffs, although flowing usually in valleys but 25 to 50 feet in depth. It is probable, however, that preglacial valleys of great depth occur which have been completely filled. So far as the writer is aware, no wells or other borings have shown the position of such valleys. Very few records were obtained in which the drift exceeds or even approaches 100 feet. The drift is very largely composed of till, but there are sand and gravel deposits in sufficient amount to furnish water ordinarily at convenient depths.

Individual wells.—The thickest drift of which a section was obtained is that penetrated by a gas-well boring on the Robinson farm, north of Adams, in the northwest part of the county, where rock was struck at about 150 feet. The drift is as follows:

	Feet.
1. Till	19
2. Sand	4
3. Blue till	52
4. Gravel and sand	15
5. Yellow till	5
6. Oily blue clay, with few pebbles	16
7. Coarse gravel	15
8. Hard blue till	20
Total	146

In the village of Adams there are drift knolls 20 or 30 feet in height. Among these knolls rock is entered at 15 to 20 feet, but on the knolls wells are obtained without entering the rock.

At Greensburg, the county seat, shallow wells are obtained at 20 to 25 feet in drift. A few tubular wells obtain their supplies from near the bottom of the drift, at about 50 feet. The waterworks supply was at first obtained from driven wells 48 to 50 feet in depth, which reached the base of the drift and obtained their supply from a layer of gravel 4 or 5 feet thick. As the supply was inadequate in seasons of drought, a well 12 inches in diameter was drilled to a depth of 75 feet, penetrating the rock 25 feet. The main supply of water was struck at 21 feet in the stone. Probably two-thirds the population of Greensburg, or about 3,000 people, obtain their supply from this well, and in addition to this the Big Four Railway Company has a monthly consumption of 2,500,000 gallons.

In the vicinity of Clarksburg and Kingston, in the northeast part

of the county, on the moraine which marks the border of the later drift, wells are obtained at 20 to 40 feet in beds of sand or gravel associated with the till.

At Mechanicsburg, in the eastern part of the county, on the older drift, the wells are obtained at 15 or 20 feet without entering rock.

In the vicinity of Letts, on the moraine in the southwest part of the county, there are several deep tubular wells. One at Boyd's store obtains water from sand below till at a depth of 90 to 98 feet. A well at the tile factory, 117 feet in depth, does not strike rock. A well at H. Mitchell's, about 3 miles west of Letts, 101 feet in depth, enters rock at 80 feet. There is thought to be a buried soil at about 60 feet. Several wells about 2 miles west of Letts enter rock at 30 feet or less, on ground fully as elevated as at Mitchell's well.

At Newburg (Forest Hill post-office) wells are obtained at about 30 feet without entering rock. Wells along a valley west from this village obtain water at a depth of 10 feet.

At Westport, on the south slope of the outer moraine of the later drift, wells in some cases enter rock at about 30 feet, but many obtain water in the drift.

At Sardinia, also near the border of the moraine, wells enter rock at 25 to 35 feet.

BARTHOLOMEW COUNTY.

General statement.—Bartholomew County is situated in the south central part of the State, with Columbus as the county seat, and has an area of 400 square miles. East White River passes through the county from north to south, slightly west of its center, following the axis of a trough or basin in the Devonian shale. There is a gradual westward descent from the east border of the county to the river valley. West from the river there is a low plain, rising gradually westward to the border of the county, where a range of prominent Knobstone hills sets in, which rises several hundred feet above the basin.

The entire county was apparently glaciated, although the glacial boundary lies but little west from the front of the prominent hills on the county line. The portion of the county east from the East White River Valley was nearly all covered by the later ice invasion, and a narrow belt along the west side of the stream in the north part of the county was also covered by that invasion. There remains, therefore, only a narrow strip on the southern and western borders of the county where the older sheet of drift alone is present. There are morainic features along the borders of the East White Valley from the north line of the county southward to the vicinity of Columbus. There are also two well-defined moraines leading eastward and northeastward from this valley across the county. The southernmost one, which lies near the line of Bartholomew and Jennings counties, marks the southern limit of the later or Wisconsin sheet of drift. The other

lies near the borders of Clifty Creek. Each of these moraines has a breadth of 2 or 3 miles, but they stand only 20 to 40 feet above the bordering plain. The surface of the older drift in this county is generally plane. The thickness of the drift ranges from a mere trace to a deposit fully 100 feet in depth. Along the East White Valley there is a gravelly belt 3 to 5 miles or more in width, and the morainic knolls just referred to appear in the midst of this gravelly district. Flat Rock Valley also contains a broad gravel plain. In the remainder of the county the drift is mainly till. Very few deep wells occur, there being generally an abundant water supply within 35 or 40 feet of the surface.

Individual wells.—At Columbus the gas-well borings penetrate about 100 feet of drift, mainly gravel, in which large amounts of water occur from a depth of 30 feet downward. The waterworks supply is from the East White River, and the greater part of the population are dependent upon it. The few private wells in use have a depth of about 30 feet.

On the gravel plain south from Columbus, in the vicinity of Wailesboro and Jonesville, wells are obtained at 20 or 30 feet, or at about the level of the water in East White River.

On the low land west of East White River wells ordinarily penetrate 8 or 10 feet of pebbleless clay, beneath which they enter till. Water is usually obtained at 20 feet or less in beds of gravel associated with the till.

The record of a well was obtained on a prominent part of the Knobstone ridge near the west border of the county in sec. 18, T. 9, R. 5 E., which reached a depth of 38 feet without entering rock. Wells often enter rock on this high land, however, at 10 or 15 feet. The well referred to has the following section:

	Feet.
1. Surface silt	8
2. Sandy material	5
3. Brown till	5
4. Blue till	20
Total	38

At a schoolhouse near this well water was obtained at only 20 feet, in a bed of sand below the surface silt.

A well near the base of the high upland, in sec. 29, T. 10, R. 5 E., 56 feet in depth, enters rock near bottom.

Records of several wells were obtained in the eastern part of the county which have a depth of 30 to 38 feet without entering rock. They are mainly through a soft till of the later ice invasion.

On the gravel plain along Flat Rock Creek, in the north part of the county, wells are usually obtained at a depth of 10 to 20 feet, or about the level of the stream.

JACKSON COUNTY.

General statement.—Jackson County is situated in the southern part of the State, with Brownstown as the county seat, and has an area of 510 square miles. East White River traverses it nearly centrally from northeast to southwest, and Muscatatuck River forms much of its south boundary. The western one-third of the county is elevated and largely unglaciated. The eastern part is mainly a low plain, though there are occasional knobs rising to heights of 200 feet or more above the plain. There is also a sharp drift ridge, 50 to 170 feet in height, leading southward from near Seymour to the vicinity of Mount Sidney. This drift ridge has a breadth of less than a mile, and is in consequence a very conspicuous feature. It is known as Chestnut Ridge, and several well sections along it are presented below.

In the eastern part of the county, between the two forks of the Muscatatuck, the drift deposits are thin, as in neighboring counties on the east, seldom reaching a depth of 50 feet; but in the district between the Muscatatuck and East White River, which includes Chestnut Ridge, the general thickness of drift is probably 100 feet, while on the ridge it may exceed 200 feet. The greater part of the drift is of a sandy constitution, though deposits of till and gravel are known to occur both in the ridge and on the bordering plain. In the southern part of the county, near the Muscatatuck, a compact clay, containing very few pebbles, constitutes the upper portion of the drift.

Individual wells.—No detailed records of wells were obtained in the unglaciated western portion of the county, but it is known that the depth there is variable, some wells being obtained at 20 feet or less, while others are 75 to 100 feet.

At Brownstown, the county seat, wells are usually about 20 feet in depth. In some instances they are obtained in the sand, but in others they enter shale a few feet.

At Seymour wells range in depth from 15 to 50 feet, and are usually driven through sand and sandy clay. The greater part of the water supply is furnished by the waterworks, and is pumped from East White River.

A gas-well boring in the northeast part of Seymour penetrates 75 feet of drift, as follows:

		Feet.
1.	Coarse sand	12
2.	Very fine sand or silt, almost a clay	43
3.	Black muck, probably an old flood plain of the river	10
4.	Coarse sand with large amount of water	5
5.	Blue clay	5
	Total	75

The black muck of this section is found quite widely in the vicinity of Seymour at a nearly uniform elevation. The thickness of the drift in the vicinity of Seymour ranges from 70 feet to 90 feet.

On the plain bordering Chestnut Ridge, south from Seymour, wells are usually obtained at a depth of 30 feet or less, though a few reach 40 feet. They are mainly through fine sand or clay, yellow at top, but of blue color at a depth of 16 to 18 feet. A flowing well on this plain is reported by Professor Cox to obtain water in a soapstone shale beneath alluvium and drift at a depth of 27 feet. The well is located on a branch of Pond Creek, in sec. 7, T. 4, R. 5 E., a few feet below the general level of the plain.

The following sections of wells were obtained on Chestnut Ridge. Harvey Morris's well, near the north end of the ridge, 89 feet in depth, penetrates—

	Feet.
1. Clay containing a few pebbles in lower part	20
2. Fine sand, becoming gravelly near bottom	69
Total	89

Jerry Anderson's well, also near north end of ridge, 95 feet in depth, penetrates—

	Feet.
1. Clay, pebbleless at surface, but quite pebbly below, and assuming a blue color in lower part	52
2. Gray sand too fine to screen, but yielding water	38
3. Gravel	5
Total	95

Hiram Love's well, 57 feet in depth, penetrates—

	Feet.
1. Surface clay and yellow till	20
2. Blue till	30
3. Gravel and sand	7
Total	57

A well at Mr. Wieneke's, on the highest point of the ridge, 77 feet in depth, penetrates—

	Feet.
1. Sandy loam	15
2. Loose sand	18
3. Reddish gravel and sand with clay admixture, probably till	40
4. Coarse gravel	4
Total	77

A strong spring gushes out of the slope of the moraine west of Mr. Wieneke's residence at about the level of the bottom of the well and probably from the same gravel bed. At M. T. Cox's residence, on a low part of the ridge, scarcely 50 feet above the bordering plain, a well 107 feet in depth penetrates—

	Feet.
1. Till	50
2. Fine sand	25
3. Gravelly sand	32
Total	107

Wells in Dudleytown, also on a low part of the ridge, obtain an abundance of water at less than 50 feet. Henry King's well, on the slope of the ridge south from Dudleytown, perhaps 30 feet above the level of the border plain, reaches a depth of 63 feet. John W. Collin's well, near the south end of the ridge, at an altitude nearly 100 feet above the plain, obtains water at 50 feet. A log was penetrated near the bottom in a sandy blue clay.

In the vicinity of Mount Sidney, on the borders of the Muscatatuck River, wells are obtained at 40 to 45 feet in sand and gravel below till. The water bed is apparently a little higher than the level of the river.

SCOTT COUNTY.

General statement.—Scott County is situated southeast of Jackson County, in the southern part of the State, with Scottsburg as its county seat. It has an area of but 190 square miles. The greater part of the county is a low plain lying along the eastern base of the Knobstone escarpment and underlain by Devonian shales. The eastern and southeastern parts, however, are more elevated and are underlain by limestone. The greater part of the county has been glaciated, but the drift deposits are usually only a few feet in thickness, rock being entered as a rule at 20 feet or less. In the north part of the county, however, on the borders of the Muscatatuck there is at least 50 feet of drift.

Individual wells.—At Scottsburg, the county seat, wells are usually obtained at 25 to 35 feet or less. The drift is about 50 feet. A gas-well boring near the railway station penetrates 47 feet of drift, as follows:

	Feet.
1. A yellowish white clay, nearly pebbleless	15
2. Sand	5
3. Blue till	27
Total	47

A boring at the fair ground, a mile southeast from Scottsburg, entered rock at 40 feet. It encountered much wood in a blue till in its lower part.

At Little York, near the west line of the county, wells usually enter shale at 15 or 20 feet, and obtain water at depths of 25 to 45 feet. Within a mile east from Little York a thicker drift sets in and wells are obtained without entering the rock at depths of 25 feet or less.

At Vienna, a well at the canning factory enters rock at 12 feet and obtains water at about 30 feet.

At Summit, or Underwood Station, near the south line of the county, wells usually enter shale at about 8 feet and obtain water at 20 to 30 feet. A well at Mr. Hosea's, one-half mile west of this village, 40 feet in depth, enters shale at 25 feet, but its water supply is from gravel at from 12 to 25 feet.

At Lexington, in the east part of the county, wells enter limestone within a few feet of the surface and obtain water at depths of 20 to 30 feet or less.

LIMESTONE DISTRICT OF SOUTHEASTERN INDIANA.[1]

General statement.—This district embraces Dearborn, Ohio, Switzerland, Ripley, Jefferson, and Jennings counties and the east part of Scott and Clark counties, an area of about 2,000 square miles. It is bordered on the southeast by the Ohio River from Lawrenceburg to Jeffersonville, Indiana.

The entire district has been glaciated, though lying entirely outside the limits of the later ice invasion, if we except a few square miles along the north border of Jennings County. On the higher parts of the upland the drift is usually but 10 to 20 feet in thickness, and is covered with a deposit of white clay nearly free from pebbles, having an average thickness of about 5 feet. The valleys and lowlands are usually filled quite deeply with drift deposits, especially in the case of the larger streams, which are as a rule occupying preglacial valleys. It is not rare to find in these valleys a drift filling to a height of 150 feet above the present beds, and the deposits, if we may judge from the depth of drift along the Ohio, probably extend 75 to 100 feet below the present streams. The drift on the uplands consists mainly of a compact clay, and strong wells are seldom obtained from this deposit. Beneath this clay there are frequently beds of black soil, which in some cases appear to be of interglacial and in other cases possibly of preglacial age. Those thought to be of interglacial age are underlain by sandy deposits, probably due, directly or indirectly, to the ice invasion. There are others which rest upon the rock strata or residuary clay, and these may be of preglacial age. Several instances of the occurrence of such soils are presented in the reports of the Indiana geological survey. In valleys the drift is often, if not generally, composed largely of sand and gravel, but has bowlders and cobble stones mixed with the finer material.

Individual wells.—The data concerning the wells here reported were obtained chiefly from the water-supply schedules sent out to various cities and villages in the district. A few were obtained while in field work, and a few are taken from the reports of the Indiana geological survey.

Along the Ohio Valley wells are usually obtained at about the level of the Ohio River at its low-water stage. The terraces are in some places fully 100 feet above the river, and wells 100 feet in depth on such terraces are not infrequent. They penetrate usually a gravel of medium coarseness, interbedded with fine gravel or sand. In places the deposits are cemented, but this feature is not a common one. The towns are taken in order from Lawrenceburg down the valley.

Lawrenceburg stands on a gravel terrace 80 to 85 feet above the low water of the Ohio, or about 505 to 510 feet above tide. The drift at

his point is shown by gas borings to be about 140 feet, reaching a evel 55 or 60 feet below the low water of the Ohio. It is composed largely of gravel, and an abundance of water may be obtained by driving pipes to the level of the river. Professor Orton calls attention, in the Geology of Ohio, to an exposure of a clayey bed near the low-water level which carries timber of several kinds. This is thought to be an old flood plain of the river. Concerning it Professor Orton remarked, "It is perhaps too early to write out this history in its minuter features, but the facts already given show us that we have in this sheet of blackened clay the bottom lands of the Ohio Valley of an earlier day, and, indeed, under very different conditions from those that now prevail. The river then ran in a channel lower by 40 feet at least than that which it now holds, and the great valley was then empty of the immense accumulations of sand, clay, loam, and gravel which constitute its bottom lands and terraces to-day."[1] A similar blackened clay has been noted at several points below Lawrenceburg, near the level of low water.

At Aurora a gas boring shows the drift to be 92 feet in depth on ground standing only 45 to 50 feet above the low water of the river. The wells in this city usually obtained water at about 50 feet near the level of low water of the river.

Rising Sun is situated on a terrace standing about 110 feet above the river in its highest part, but the town extends down the slope to a level only 60 feet above the river. Wells at the level of the top of the terrace have, in some instances, been sunk to the level of the river, one well at Cornelius Harris's being 114 feet and one at J. M. Pate's 112 feet in depth. Mr. Pate's well obtained some water at 27 feet, and weak wells are often obtained at about that level on the terrace. The drift at Mr. Pate's well is mainly sand, but a bed of blue mud was passed through at about 50 or 60 feet. A well at an old mill on the river bank 120 feet in depth reached a level 60 feet below the low water of the river without encountering rock. Only a half mile above the mill, on the Kentucky side, rock extends half way across the river channel at level of low water.

At Vevay wells are usually obtained at a depth of 60 to 80 feet, but occasionally reach a depth of 100 feet. The terrace on which the main part of the town stands is about 80 feet above low water. It is composed largely of fine gravel, which is cemented in places at depths of 20 to 50 feet. The supply for the waterworks at Vevay is pumped from the Ohio River.

At Carrollton, Kentucky, 8 miles below Vevay, Mr. J. F. Jett made a boring at his distillery, near the mouth of the Kentucky River, 107 feet in depth, which reaches a level 50 feet below the low water of the Ohio, without striking rock. The boring was stopped in a cemented gravel.

At the city of Madison, Indiana, several wells on a terrace standing

[1] Geol. Ohio, Vol. I, p. 429.

90 to 100 feet above the river have reached a depth of 120 feet without entering rock. The terrace in the eastern portion of the city is underlain by a coarse gravel, but in the western portion the drift becomes sandy. The waterworks obtain a large part of the supply from the Ohio River by infiltration into a large well excavated at the side of the river. A portion of the supply is from springs in the west part of the city. Probably half of the population still depend upon private wells and cisterns, there being only about 1,200 private connections with the waterworks in a population of 10,000.

At Jeffersonville wells are obtained at a depth of 40 or 50 feet in sand and gravel, water being found at about the low-water level of the river above the Louisville rapids. A few drilled wells enter the hydraulic limestone 8 to 12 feet. This limestone is struck in portions of the city just below the level of low water.

Statistics concerning wells were obtained at several villages on the uplands in these southeastern counties of Indiana, as follows: At Versailles, the county seat of Ripley County, wells are obtained at depths of 18 to 25 feet in the upper part of the limestone. At Osgood wells are usually obtained near the base of the drift at depths of 9 to 15 feet. Occasionally wells are drilled to a depth of 100 feet or more in the northern part of Ripley County. At North Vernon, in Jennings County, wells are obtained at depths of 12 to 35 feet, the majority being about 25 feet. They usually enter the rock a few feet. The waterworks obtain a supply from the Muscatatuck River. The village of Vernon also obtains its waterworks supply from the Muscatatuck River. At Charlestown, formerly the county seat of Clark County, wells are obtained at a depth of 30 to 35 feet, usually in the Corniferous limestone. A few, however, reach this depth without entering rock. In wells where drift 25 to 30 feet in thickness is penetrated it is quite common to find a blue mud carrying tree trunks or small pieces of wood near the base of the drift. Rock is ordinarily struck in this village at about 12 feet. There are four very strong springs within the corporate limits of the town, which are made use of by many of the residents.

The following sections of wells on the uplands, taken from the reports of the Indiana Geological Survey, are of interest in showing the presence of a buried soil. Mr. N. Van Osdel's well, in the broken upland of Ohio County, sec. 6, T. 3, R. 2 W., penetrates—

	Feet.
1. Soil and clay	22
2. Yellow sand, quite hard or cemented	9
3. Blue clay, hard, without pebbles	1½
4. Black soil containing rotten leaves, twigs, and wood, thought to be walnut	1½
5. Coarse sand, gravel, and shelly stone	9
6. Hard blue limestone	1
Total	44

At Mr. J. B. Gordon's, sec. 4, T. 5, R. 12 E., in the northwest part of Switzerland County, a well penetrates—

	Feet.
1. Soil and clay, pale in lower part	22
2. Blue mud resembling recent alluvium	6
3. Black soil, containing leaves, cedar wood, and ocherous particles	3
4. Small stones closely packed together	1
Total	32

It is thought that the bottom bed in this well is native rock. A neighboring well struck leaves and poplar bark at 32 feet. Wells in that vicinity often enter rock at 10 to 14 feet. In the vicinity of Paris Crossing, in the extreme southern part of Jennings County, buried timber is often found in digging wells on land 60 to 70 feet above the bed of Graham Creek. In one well sunk by Mr. John F. Files it is estimated that at least a half cord of wood was taken from a well at a depth of 32 to 40 feet. The wood appears to be birch, and specimens were sent to the State museum. The wood is much crushed and twisted, but it was found suitable for fuel and was thus made use of by Mr. Files. The following is the section of the beds penetrated—

	Feet.
1. Light-colored clay with darker shades below	10
2. Ocher-colored clay with flint pebbles, increasing in hardness toward the bottom	19
3. Very hard bed of clay and gravel	2 to 3
4. Sandy blue clay, with water; also limbs, twigs, and roots of trees	7 to 10
Total	38 to 42

The ingress of water prevented the deepening of the well, and the wall was commenced on the driftwood at its bottom. A well at South Milan, in eastern Ripley County, 54 feet in depth, did not enter rock, though quarries are opened in that vicinity at about the level of the well mouth. The following is a section of the well made by the railway company:

	Feet.
1. Light-colored clay	10 to 14
2. Yellow clay, with flint, gravel, and fossil corals	12
3. Blue glacial clay	12
4. Coarse yellow sand, with recent shells and water	8
5. Blue clay and muck, containing roots and limbs of trees	8
Total	54

KNOBSTONE BELT OF SOUTHERN INDIANA.

The portion of this belt outside the drift border covers the greater part of Brown and Jackson counties, western Bartholomew, northeastern Washington, western Scott, western Clark, and a narrow strip in Floyd and Harrison counties, an area of about 1,200 square miles. Its ridges stand 800 to 1,150 feet above tide and comprise the highest land *in that part of* the State. The writer is personally

acquainted with but a small part of this belt and has found but few published data bearing upon its capacity for supplying wells. In the roughest portions agriculture is carried on with difficulty, and the few residents depend largely upon cisterns and springs; but in the less rugged and more thickly settled portions wells are said to be in use. Nothing has been learned to indicate that difficulty is experienced in obtaining water of good quality at convenient depths. The few wells reported show an average depth of but 20 to 30 feet.

LIMESTONE BELT OF SOUTHERN INDIANA.

The portion of this belt outside the drift border covers the greater part of Monroe, Lawrence, Washington, Orange, and Harrison counties, also western Floyd and eastern Crawford counties, a combined area of about 2,000 square miles. This limestone belt has generally an abundance of good water within 50 feet of the surface, and good wells 30 feet in depth are not rare. In a few cases wells have been sunk to depths of 100 to 150 feet, with a view to increasing the amount of water. However, the few data at hand seem to indicate that the chances for obtaining fresh water in the upper 100 feet are better than at lower depths. The early settlers made open wells, but in recent years drilled wells are coming into use. The latter are sunk to a greater average depth than the former, but are seldom more than 100 feet. The extreme hardness of the water is also objectionable and has led to extensive use of rain water collected in cisterns.

Some of the strong sulpho-saline wells and springs of southern Indiana which have gained wide reputation for medicinal properties are obtained in this limestone. There are many salt and sulphur springs which have never been brought to public notice on account of their difficult accessibility or other adverse conditions. Some wells and springs were used in the manufacture of salt, on a small scale, in the early days of settlement, before the great salt industries of the neighboring States were developed. Salt Creek, one of the main tributaries of East White River, receives its name from springs of salt water found on its middle and lower courses.

CONGLOMERATE SANDSTONE OF SOUTHERN INDIANA.

This sandstone forms a narrow belt along the west border of the limestone, its average width of outcrop being scarcely 10 miles. Like the Knobstone belt, it is characterized by sharp ridges and hills, which are but sparsely settled, agriculture being carried on with difficulty. The water afforded by springs, together with cistern water collected from roofs of dwellings, often supply the needs of the residents. Wells are apparently less common than in the limestone district on the east, and are far less numerous than in the Coal Measures basin that borders it on the west. The few available data concerning wells in this sandstone indicate that a fair supply of water may be obtained at convenient depths.

COAL MEASURES BASIN OF SOUTHWESTERN INDIANA.

Under this head is included the portion of western Indiana south from Vigo, Clay, and Owen counties covered by the Coal Measures sandstone and shale, an area of about 4,500 square miles. Fully two-thirds of this region has a thin coating of drift. The remainder is driftless, except a coating of loess.

The loess seldom affords a supply of water for wells, as it is usually but 5 to 10 feet in depth. The glacial drift may be depended upon in perhaps half its extent in this region to supply a sufficient amount of good water for the needs of the residents. Where it exceeds 20 feet in depth there is usually present a water-bearing bed which will supply wells for household use. Occasionally wells strong enough to supply the stock on a farm are obtained from drift deposits, but the strong wells are usually obtained from the rock. Along the Wabash Valley, however, strong wells are generally obtained in glacial deposits at shallow depths, there being a heavy deposit of water-bearing gravel in the valley.

Along the Ohio Valley above Mount Vernon there are extensive bottom lands, in which a compact clay must be penetrated 60, 80, and occasionally 100 feet or more before water-bearing sand or gravel is reached. Similar bottoms occur in Evansville and just above the city. Farther east, between Yankeetown and Rockport, wide bottoms are underlain by sand, in which wells are obtained at depths of but 20 to 40 feet. Many of these wells overflow and afford excellent water.

Where wells are not obtained in the drift they are usually obtained in the underlying rock at convenient depths—30 to 60 feet, or less. The wells in the driftless portion also usually obtain water at convenient depths. The water in these shallow wells in rock is in some localities objectionable because of sulphates, and is known as "copperas water," but the great majority of wells yield water of pleasant taste and harmless quality.

A few wells have been sunk to depths of 200 feet or more which obtained fresh water. Coal shafts also have in some cases struck fresh water at similar depth. The chances, however, are against obtaining fresh or potable water from such depths, and the residents usually make use of large cisterns if water can not be obtained in suitable amount from shallow wells.

INDEX TO PLACES.

	Page.
	50
	18
	11
	28
	35
	26
	11-12
	22
	36
	45
	19-20
	57
	25
w County	51-52, 59-60
	34
	23
e	23
y	13-17
en	45
	45
	28
	27
	48-49
ty	59-60
	26
	53
	34
	31
ity	33
	45
	13
ty	57
	36
	28
	21
	49
	33
rg	20
	58
	13
y	56-60
	50-51
	13
	45
	44-45
	26
	21
	26
	52
	35
	45
	20
unty	60
lle	18-19
	27
	39
	10
	33
	26
unty	56
nty	49-51
unty	9-10
	55
	31
	13
	10
	42
	15
	11
	49
	21
	61
	49

	Page.
Fairland	38
Farmland	8
Fayette County	34-35
Fincastle	25
Fishers Station	13
Floyd County	59-60
Fontanet	46-47
Forest Hill	51
Fountain City	32
Fountain County	19-20
Franklin	41, 42
Franklin County	48-49
Frankton	12
Glenwood	36
Gosport	44
Greenfield	29
Greensboro	31
Greensburg	50
Greenwood	41
Hagerstown	32
Hamilton County	12-13
Hamilton Station	36
Hancock County	29
Harmony	45
Harrison County	59-60
Hendricks County	25-26
Henry County	29-31
Homer	36
Honeycreek Station	31
Howard	23
Huntsville	12
Indianapolis	27-28
Irvington	27
Jackson County	53-55, 59-60
Jackson Township	24
Jackson Township	38
Jamestown	16, 17
Jefferson County	56-59
Jeffersonville	58
Jennings County	56-59
Johnson County	40-42
Jolietville	13
Jonesville	52
Kennard	31
Kingston	50-51
Knightstown	31
Knightsville	45
Laurel	49
Lawrence	27
Lawrence County	60
Lawrenceburg	56-57
Lebanon	15-17
Lena	45
Letts	51
Lewisville	31
Lexington	56
Liberty	34
Little York	55
Lizton	26
Lodi	20
Lodi	23
Losantville	9
Lotus	34
Luray	30
Lynn	9
McCordsville	29
Madison	57-58
Madison County	10-12
Manilla	38-39
Marion County	26-28
Markleville	12
Marshall	23
Martinsville	43, 44

	Page.
Mechanicsburg	51
Metamora	49
Middletown	31
Mill Creek Township	20
Milledgeville	17
Monroe County	60
Monrovia	43
Montezuma	23
Montgomery County	18-19
Moreland	30
Morgan County	42-43
Morgantown	43
Mount Auburn	38
Mount Sidney	55
Mount Summit	30
Mount Vernon	61
Muncie	10
New Brunswick	17
New Palestine	29
New Salem	36
New Trenton	49
Newburg	51
Newcastle	30
Newtown	21
Nineveh	42
Noblesville	12-13
North Salem	25-26
North Vernon	58
Northfield	15
Oakland	27
Ogden	31
Ohio County	56
Oldenburg	49
Orange County	60
Osgood	58
Owen County	43-44
Paris Crossing	59
Parke County	21-24
Parker	8
Pendleton	12
Peppertown	49
Perth	45
Philadelphia	29
Plainfield	26
Pleasant Hill	18
Posey County	61
Prairie City	45
Putnam County	24-25
Quincy	44
Raleigh	36
Randolph County	7-9
Ratsburg	16
Reno	26
Richmond	32, 33
Ridgeville	8
Ripley County	56-59
Rising Sun	57
Rockport	61
Rockville	23
Rosedale	23-24

	Pa
Roston	
Royalton	
Rush County	35
Rushville	
St. Paul	
Saline City	
Sardinia	
Scott County	55
Scottsburg	
Selma	
Seymour	
Shelby County	37
Shelbyville	38, 39
Sheridan	
Shideler	
Slabtown	
South Milan	
Spencer	
Spencer County	
Spiceland	
Springport	
Stone Bluff	
Sulphur Springs	
Summit	
Summitville	
Switzerland County	
Terre Haute	
Thorntown	14,
Underwood Station	
Union Church	
Union City	
Union County	33,
Union Village	
Vanderburg County	
Veedersburg	
Vermilion County	20-
Vernon	
Versailles	
Vevay	
Vienna	
Vigo County	46-
Wailesboro	
Waldron	
Walnut Level	
Warrick County	
Washington	
Washington County	59,
Wayland	
Wayne County	31,
West Union	
Westfield	
Westport	
Wheeling	
Williamsburg	
Williamsburg	
Winchester	
Windsor	
Yankeetown	
Zionsville	

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DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 27

WASHINGTON
GOVERNMENT PRINTING OFFICE
1899

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

OPERATIONS AT RIVER STATIONS, 1898

A REPORT OF THE

DIVISION OF HYDROGRAPHY

OF THE

UNITED STATES GEOLOGICAL SURVEY

PART I

WASHINGTON

GOVERNMENT PRINTING OFFICE

1899

CONTENTS.

	Page.
f transmittal	6
tion	7
ı Atlantic coast drainage	9
ı Atlantic coast drainage	25
Gulf drainage	47
er drainage	59
ıkes drainage	66
issouri River drainage	68
iver drainage	76
River drainage	89
on tables	96

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, March 1, 1899.

SIR: I have the honor to transmit herewith a manuscript giving the results of operations at the river stations in the eastern and central portions of the country during the calendar year 1898, together with related data, for publication in the series of papers upon water supply and irrigation. The data for the western portion of the country (Part II) will be transmitted as the succeeding number of the series.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

Hon. CHARLES D. WALCOTT,
Director United States Geologicaal Survey.

'PERATIONS AT RIVER STATIONS, 1898,

PART I.

INTRODUCTION.

The following pages contain descriptions of the river stations main-
ned during 1898 by the United States Geological Survey, together
h tables of the average daily height of water, results of measure-
nts of discharge, and rating tables constructed from the latter and
licable in general for the calendar year. Similar facts have been
ated for the year 1896 in Water-Supply Paper No. 11, and for 1897
Water-Supply Papers Nos. 15 and 16. In the papers mentioned
description of each station has been given, next the date and
ult of each measurement, followed by the table of daily gage
ghts. In the present manuscript the order has been modified in
er to secure a more concise presentation. The stations have been
uped in geographic order, and for each group the descriptions of
of the stations have been given; following these all of the gage
ghts for the group, then all of the discharge measurements and
rating tables. In the case of river stations, where the changes
e been trivial in character, the descriptions have not been repeated,
reference made to the page of preceding papers where more fully
cribed.

he material above noted consists essentially of the results of
rations at the river stations, and forms the basis for computations
laily, monthly, and annual flow. In order to make these neces-
computations considerable time and labor is involved and the
ulting facts can be most clearly and concisely given by diagrams.
preparation of the computations and the diagrams necessitates
voidable delays, and therefore it has been the custom to present
facts, such as are given herewith, as soon as possible after the
e of the calendar year, so that the original data may be available
n early date to all who are concerned with their use. While these
inal figures are being printed the computations of final results
being prepared, and, with the illustrations, have in the past been
le to form a part of the annual report of the Director of the
logical Survey. For example, the results for 1896, mentioned
ve, as given in Water-Supply Paper No. 11, are fully discussed in
t IV of the *Eighteenth Annual* Report, also the original data for

1897, given in Water-Supply Papers Nos. 15 and 16, are published in final form in the Nineteenth Annual Report, Part IV. In the same way the figures herewith given form the basis for conclusions, being prepared for publication in Part IV of the Twentieth Annual Report.

Most of the measurements herewith presented have been obtained through local hydrographers, a comparatively small part of the work having been conducted directly from the office of the Geological Survey at Washington. Acknowledgment is therefore due to each of these persons individually. Thanks should also be extended to individuals and corporations who have cooperated in various ways, either by furnishing readings of height of water or assisting in transportation. The following list gives the names of the resident hydrographers or persons cooperating, this being arranged alphabetically by States:

Arizona: W. A. Farish, civil engineer, Phœnix; Albert T. Colton, civil engineer, Florence.

California: J. B. Lippincott, civil engineer, Los Angeles.

Colorado: A. L. Fellows, deputy State engineer, Denver.

Georgia and Alabama: Prof. B. M. Hall, civil engineer, Atlanta, Ga., and Prof. W. S. Yeates, State geologist, Atlanta.

Idaho: Frank S. Shirley, civil engineer, Boise.

Kansas: W. G. Russell, Russell; Prof. E. C. Murphy, State University, Lawrence.

Maryland: Prof. W. B. Clark, State geologist, Baltimore.

Montana: S. M. Emery, director experiment station, Bozeman; and Roe Emery, Bozeman.

Nebraska: Prof. O. V. P. Stout, State University, Lincoln, assisted by Adna Dobson and Glenn E. Smith.

Nevada: L. H. Taylor, civil engineer, Golconda.

New Mexico: P. E. Harroun, civil engineer, Santa Fe.

North and South Carolina: Prof. J. A. Holmes, State geologist, Chapel Hill, N. C., assisted by E. W. Myers.

Texas: Prof. Thomas U. Taylor, State University, Austin.

Utah: Prof. Samuel Fortier, civil engineer, Corinne.

Virginia and West Virginia: Prof. D. C. Humphreys, Washington and Lee University, Lexington, Va.

Washington: Sydney Arnold, civil engineer, North Yakima; William J. Ware, civil engineer, Port Angeles.

Wyoming: Clarence T. Johnston, civil engineer, Cheyenne.

In a number of instances related data have been inserted, such, for example, as results of computation of daily flow at mill dams, made by local engineers, and data of river heights obtained from the United States Weather Bureau or Corps of Engineers, United States Army. Reference to these facts, mainly unpublished, has been, or will be, made in other publications of this survey, and they are, therefore, placed in consecutive order for convenience of reference.

The methods of measurement of discharge of the various streams nd the computations have been described in a general way on pages 8-30 of the Nineteenth Annual Report, Part IV. There has been radual progress and development of details, but the operations there escribed have remained essentially unchanged.

NORTHERN ATLANTIC COAST DRAINAGE.

DESCRIPTION OF RIVER STATIONS.

aterville station on Kennebec River.—Computations of discharge ' Kennebec River at Waterville, Maine, have been made by Mr. ımner Hollingsworth, president of the Hollingsworth & Whitney ompany, those beginning on November 15, 1891, being fragmentary ı character through 1892. Prior to June 20, 1893, computations are ısed upon the flow over the dam as determined by weir formula. ıbsequent to that date figures are from computations of the flow rough turbines, using assumed readings, to which has been added ıy excess passing over the crest of the dam. The figures really give e discharge at noon on each day, this hour being the time when the ıw is least affected by storage of dams upstream, and as giving most adily the average for the day. A summary of results is given on ge 75 of the Nineteenth Annual Report, Part IV.

Rumford Falls station on Androscoggin River.—Computations of ıcharge made of Androscoggin River at Rumford Falls are described page 92 of the Nineteenth Annual Report, Part IV. They begin May 18, 1892, and extend to the end of April, 1895. Until Janu- ɣ, 1893, the discharge was determined from the computed flow over ɜ dam, as given by Francis's ordinary weir formula. Subsequent that time, as water was used for power, additions were made to ɜ computed flow over the dam of the amounts assumed to pass rough the turbines, until July, 1895. Since that date the quanti- s are the sums of the actual measured quantities passing through ɜ wheels and the computed flow over the dam. The gage readings ɜ taken at the lower dam, and at first were made once a day, later ır times a day, and subsequently every two hours. The results ve been kindly furnished by Mr. Charles A. Mixer, resident engi- ɜr of the Rumford Falls Power Company. A summary of the ıults is given on page 93 of the Nineteenth Annual Report, rt IV.

Lambertville station on Delaware River.—Described on page 7 of per No. 15; results for 1897 shown on page 122 of the Nineteenth ınual Report, Part IV.

Harrisburg station on Susquehanna River.—Described on page 8 Paper No. 15; results for 1897 given on page 122 of the Nineteenth ınual Report, Part IV.

Rowlandsville station on Octoraro Creek.—Described on page 12 of Paper No. 15; results for 1897 given on page 128 of the Nineteenth Annual Report, Part IV.

Woodstock station on Patapsco River.—Described on page 13 of Paper No. 15; results for 1897 given on page 129 of the Nineteenth Annual Report, Part IV.

Laurel station on Patuxent River.—Described on page 14 of Paper No. 15; results for 1897 shown on page 131 of the Nineteenth Annual Report, Part IV.

Sharpsburg station on Antietam Creek.—Described on page 16 of Paper No. 15; results for 1897 shown on page 149 of the Nineteenth Annual Report, Part IV. On January 26, 1898, a United States Geological Survey standard copper bolt bench mark was set in a rock on the left bank of the stream, 150 feet upstream from the point where the cable enters the ground. This is 16.34 feet above gage datum.

Port Republic station on North and South rivers.—Described on page 17 of Paper No. 15; result for 1897 shown on page 138 of the Nineteenth Annual Report. Part IV. No measurements were made on these rivers in 1898.

Millville station on Shenandoah River.—Described on page 19 of Paper No. 15; results for 1897 shown on pages 150 and 151 of the Nineteenth Annual Report, Part IV.

Frederick station on Monocacy River.—Described on page 20 of Paper No. 15; results for 1897 shown on page 154 of the Nineteenth Annual Report, Part IV.

Point of Rocks station on Potomac River.—Described on page 21 of Paper No. 15; results for 1897 shown on page 152 of the Nineteenth Annual Report, Part IV.

Park station on Rock Creek.—Described on page 22 of Paper No. 15; results for 1897 given on page 155 of the Nineteenth Annual Report, Part IV. No rating table was constructed for lack of sufficient data.

Glasgow station on North of James River.—Described on page 23 of Paper No. 15; results for 1897 given on page 162 of the Nineteenth Annual Report, Part IV.

Buchanan station on James River.—Described on page 24 of Paper No. 15; results for 1897 given on page 172 of the Nineteenth Annual Report, Part IV. The observer is W. H. Hyde. The temporary bench mark is the upper end of the fifth floor beam from the left bank. It is at an elevation of 30 feet above the zero of the gage.

TABLES OF DAILY DISCHARGE AND GAGE HEIGHT.

Discharge of Kennebec River at Waterville, Maine, in cubic feet per second, average for the twenty-four hours.

[Drainage area, 4,410 square miles.]

1892.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
				3,530		11,840	17,355					
				4,730	7,920		20,030					
				10,260		11,840						
				19,100	6,310		29,985					
				25,250								
				22,980	8,950	11,515						
				28,150								
				24,830		8,200						
				22,810	9,660							
						7,925						
				18,090	5,900							
				11,195	7,650	7,375						
											a545	
				8,660		7,100					a395	
											a670	
					6,940	8,490					a639	
				6,940	6,580						a568	
											a961	
				6,465	5,310	10,260					a1,449	
											a1,488	
			2,470	7,530		17,355					a1,112	
				9,835	7,215							
			2,430			19,640					a958	
			2,250		13,750	21,615					a1,399	
			2,220								a2,296	
			2,000	13,160	10,750	19,250						
			2,325			19,640						
			2,390	8,780		29,990						
			2,730		12,160	20,030						
			3,080									

a These figures are for the year 1891. The closing of gates at Moosehead Lake is said to have reduced the small discharge here recorded.

1893.

		2,350	2,500	4,100	21,700	13,200	10,840	1,940	2,490		1,980	2,780
		2,250	2,500	4,250	21,200	16,250		2,330	2,140	1,980	1,980	2,580
		2,200	2,450	4,500	27,600	15,200	9,990	2,380		1,980	1,980	
		2,100	2,400	4,400	24,700		11,230	2,360	1,890	1,710	1,980	
		2,100	2,400	3,700	60,500	13,800	8,840	2,290	1,890	1,980		1,440
		2,200	2,400	3,700	46,500	15,250	9,740		1,890	1,980	1,980	1,440
		2,300	2,350	3,600	36,700	16,250	8,410	2,240	2,260	1,980	2,250	1,440
		2,250	2,350	3,600	30,200	18,200	8,410	2,210	2,360		1,980	1,440
		2,100	2,325	6,400	26,300	23,500		2,360	2,680	1,980	1,980	1,440
		3,000	2,300	9,200	25,200	15,900	8,260	2,360		1,980	1,980	
		2,400	2,300	12,400	27,000		8,710	2,290	2,160	1,710	1,980	1,440
	2,000	2,550	2,300	15,000	31,700	16,250	6,510	2,290	2,380	1,440		1,440
	2,100	2,600	5,400	16,500	31,300	23,200	6,410		2,190	1,780	1,980	1,440
	2,300	2,550	8,000	16,500	54,500	20,500	6,040	2,240	2,410	1,980	1,980	1,440
	2,500	2,500	11,300	18,200	43,100	18,200	5,540	2,290	2,340	4,000	1,980	1,440
	2,600	2,400	7,400	16,500	34,100	15,200		2,430	2,175	3,050	1,980	1,440
	4,800	2,300	6,300	14,100	30,700	13,200	4,840	2,210		2,550	1,980	
	5,000	2,200	6,100	14,000	83,500	13,200	4,490	2,150	1,710	2,550	2,250	1,710
	4,200	2,100	5,700	14,100	46,100	11,200	3,660	2,290	1,710	1,980		1,710
	3,200	2,200	5,600	16,300	34,500	11,000	3,270		2,200	2,250	2,250	1,440
	2,100	2,350	4,600	14,500		12,000	3,590	2,240	1,710	1,980	2,520	1,440
	1,900	2,450	3,900	12,300	24,300	14,480	3,490	2,205	1,710		2,250	1,440
	2,100	2,350	3,600	13,800	22,800	13,640		2,180	1,710	1,980	2,550	1,440
	2,200	2,200	3,600	15,800	21,200	11,840	3,170	2,153		1,980	2,480	
	2,300	2,400	4,000	14,500	19,800		2,830	2,295	1,710	3,380	1,980	
	2,200	2,400	4,400	14,600	17,000	14,270	2,440	2,390	1,710	2,450		1,440
	2,200	2,450	4,400	14,200	16,300	14,000	2,380		1,980	1,980	1,980	1,590
	2,300	2,500	4,300	14,600	15,200	15,100	2,360	2,340	1,980	3,630	2,080	1,440
	2,300		4,200	14,800	14,550	14,600	2,240	2,310	1,710	3,530	3,980	1,590
	2,350		4,100	19,800	13,600	13,500		2,230	1,980	3,280	3,630	1,590
	2,400		4,000		13,900		2,440	2,430		2,280		
Mean	2,650	2,350	4,180	11,660	30,520	15,290	5,770	2,270	2,040	2,330	2,230	1,580

Daily discharge of Kennebec River, at Waterville, Maine, in cubic feet per second, average for the twenty-four hours—Continued.

1894.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1,470	1,910	1,740	.....	15,650	11,190	.....	3,305	2,253	2,181	3,896	1,570
2	1,640	1,910	1,740	4,496	14,510	12,930	7,030	3,240	1,125	1,923	7,295	.....
3	1,640	1,740	1,740	4,496	14,090	.....	6,860	3,143	2,312	1,915	5,619	2,187
4	1,640	.....	.....	4,370	13,220	12,930	.....	3,218	1,871	1,930	10,512	2,194
5	1,640	1,910	2,010	4,370	13,220	10,400	10,020	.....	2,207	1,896	9,486	2,213
6	1,640	1,910	1,740	5,473	.....	9,070	8,570	3,087	1,824	1,655	7,381	1,869
7	.....	1,740	1,910	4,720	12,280	9,070	7,065	3,019	2,209	.....	5,606	2,193
8	1,640	1,740	2,370	.....	10,100	8,520	.....	3,019	2,185	1,897	4,651	2,128
9	1,470	1,740	3,040	5,278	8,550	6,910	7,055	3,285	1,140	1,913	3,937	1,245
10	1,640	1,740	4,643	5,655	7,226	.....	6,336	3,045	2,293	1,913	3,739	1,937
11	1,640	.....	.....	5,950	7,050	5,900	6,674	3,050	2,034	5,553	3,040	1,211
12	1,470	1,740	5,390	6,980	6,110	.....	6,674	.....	2,818	6,738	3,636	1,694
13	1,640	1,740	5,390	7,170	.....	6,280	6,674	3,250	2,280	5,017	3,476	1,819
14	.....	1,740	6,220	6,980	5,840	5,900	6,336	3,125	2,309	8,387	2,782	2,386
15	1,470	1,740	5,580	.....	6,820	6,010	.....	3,005	2,341	9,036	2,500	2,600
16	1,640	1,740	4,460	12,150	7,410	5,900	6,674	3,010	.....	3,829	2,661	2,275
17	1,640	1,740	4,855	13,310	9,935	.....	6,046	3,110	2,183	7,527	2,489	2,513
18	1,470	.....	.....	20,640	9,935	.....	5,765	3,060	2,136	6,418	2,152	2,466
19	1,640	1,740	4,140	21,760	10,915	5,520	5,100	.....	1,883	5,088	2,631	2,331
20	1,640	1,740	5,405	22,910	.....	9,565	5,550	3,230	1,885	4,253	1,984	2,326
21	.....	1,760	3,802	26,860	13,540	10,055	4,885	3,050	12,102	3,231	2,446	2,205
22	1,640	1,760	6,660	.....	8,250	5,490	.....	2,915	6,659	3,730	2,502	2,208
23	1,640	1,810	6,395	35,280	6,100	6,265	3,680	2,825	4,673	3,576	2,495	1,229
24	1,640	1,810	5,215	33,680	6,360	.....	3,565	3,070	4,143	3,315	2,487	1,912
25	1,910	.....	.....	29,130	6,580	3,930	3,670	2,555	2,646	2,549	2,786	.....
26	1,910	1,760	4,855	25,210	10,560	3,781	3,830	.....	2,571	2,605	2,484	.....
27	1,910	1,740	4,184	21,980	.....	3,710	3,830	2,855	2,509	2,854	2,461	1,831
28	.....	1,740	4,180	20,680	8,690	10,480	3,830	2,494	2,378	.....	2,515	1,770
29	1,640	.....	3,895	.....	7,480	8,985	.....	2,615	1,918	2,859	1,444	1,657
30	1,640	.....	3,620	17,450	7,960	8,070	3,415	2,294	467	2,458	1,845	904
31	1,640	.....	3,510	.....	10,000	.....	3,345	2,400	.....	2,452	.....	1,227
Mean	1,640	1,780	4,020	14,680	9,570	7,790	5,720	2,970	2,740	3,750	3,760	1,930

1895.

1	1,135	2,214	1,685	2,176	13,227	9,818	5,042	3,153	1,792	1,106	1,081	5,904
2	1,599	2,208	1,687	2,205	11,967	9,314	4,315	3,062	2,867	1,149	1,347	4,682
3	1,655	1,733	1,252	2,406	11,461	8,408	4,278	3,063	2,560	1,130	1,870	8,378
4	1,664	2,174	1,720	2,638	12,172	7,979	3,784	1,576	2,226	1,110	1,421	5,842
5	1,608	2,444	2,229	6,164	11,934	7,364	4,062	3,015	2,212	1,152	2,201	3,519
6	1,780	2,077	2,145	7,691	12,584	7,370	3,844	2,738	2,200	.....	1,946	2,723
7	1,678	1,854	1,956	9,286	12,764	7,425	4,429	2,610	2,155	1,128	1,708	3,273
8	1,947	1,718	1,951	9,325	10,917	7,623	4,499	2,816	1,438	1,104	1,657	2,301
9	1,894	1,622	1,949	24,407	12,074	6,166	4,039	2,580	2,250	1,126	1,426	3,393
10	1,896	1,397	1,368	54,192	7,848	6,418	4,072	2,382	2,502	1,356	5,125	3,089
11	1,889	1,983	1,683	27,999	9,630	5,852	3,993	1,529	2,256	1,109	9,595	3,105
12	1,864	1,946	1,920	20,858	7,920	6,454	3,934	2,690	2,209	1,121	8,351	2,598
13	1,273	1,943	1,932	19,304	11,352	4,854	3,731	2,435	1,996	.....	6,279	2,278
14	2,403	1,967	1,946	24,061	16,175	5,887	3,658	2,405	1,970	1,185	3,882	2,524
15	2,441	1,648	2,236	86,201	12,878	6,925	3,767	2,160	1,150	1,141	3,869	1,747
16	2,481	1,950	2,224	70,381	12,121	6,592	3,631	2,433	1,736	1,134	4,972	2,545
17	2,490	579	1,566	43,408	9,842	6,156	3,508	2,118	1,710	1,250	6,455	2,069
18	2,509	2,112	2,224	34,708	7,895	6,121	3,546	857	1,987	1,546	5,695	2,621
19	2,439	1,708	2,194	31,068	8,668	5,616	3,512	2,681	1,721	1,587	4,591	1,928
20	1,817	1,689	1,937	31,562	7,807	5,905	3,232	2,072	1,741	.....	4,169	2,180
21	2,439	1,361	1,965	31,363	5,863	5,641	3,257	2,357	1,707	1,353	10,949	2,536
22	2,304	1,656	1,946	29,572	5,449	4,497	2,617	2,240	1,050	1,422	11,179	3,321
23	2,332	1,606	1,977	28,511	5,515	5,075	3,151	2,199	1,139	1,428	6,694	11,026
24	2,290	.....	1,627	23,707	8,261	5,046	2,875	2,722	1,387	1,432	5,124	9,147
25	2,333	1,629	2,241	20,348	8,037	5,670	2,863	1,658	1,167	1,372	5,632	6,136
26	2,319	1,676	2,314	18,931	6,919	6,216	2,590	4,284	1,155	1,399	4,804	5,162
27	1,706	1,714	2,769	15,489	7,593	6,290	2,552	5,089	1,104	.....	9,383	5,792
28	2,433	1,927	2,600	15,929	8,119	5,708	2,096	4,890	1,145	1,115	15,900	26,673
29	2,198	.....	2,418	10,853	6,109	5,690	2,671	3,450	.....	1,355	11,623	16,148
30	2,439	.....	2,459	13,216	4,868	4,955	2,930	3,080	1,115	1,385	9,372	14,590
31	2,127	.....	1,898	.....	8,982	.....	2,678	3,102	.....	1,081	.....	19,713
Mean	2,040	1,800	2,000	23,930	9,580	6,430	3,520	2,690	1,780	1,250	5,610	6,030

Daily discharge of Kennebec River at Waterville, Maine, in cubic feet per second, average for the twenty-four hours—Continued.

1896.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3,281	2,643	6,257	5,527	29,468	7,491	4,811	3,730	2,643	2,870	3,238	8,049
2	21,881	1,292	111,246	5,861	26,601	11,004	4,374	2,696	2,611	2,975	4,259	6,844
3	17,367	2,717	52,691	6,647	25,207	6,846	4,236	3,595	1,772	3,734	4,023	5,730
4	11,482	2,522	24,810	6,442	18,064	5,891	5,578	3,597	2,577	2,275	3,757	2,200
5	6,708	2,243	13,866	5,782	26,583	5,318	5,249	3,037	2,371	5,249	3,435	2,603
6	4,153	2,236	13,170	5,709	30,879	4,961	11,678	3,044	2,129	4,567	29,865	2,545
7	3,803	2,857	11,862	5,373	29,499	4,343	11,214	3,313	6,903	3,954	23,836	3,312
8	4,329	4,634	10,323	4,998	25,090	4,391	9,685	3,468	7,978	3,277	17,040	2,851
9	2,970	3,962	8,950	5,040	22,228	4,374	8,690	.....	6,094	3,210	15,322	2,870
10	2,971	3,452	9,499	5,199	19,997	5,953	7,149	4,113	4,624	3,166	12,152	2,852
11	3,006	3,140	5,469	6,757	20,249	3,855	6,047	4,737	4,003	2,394	10,028	2,851
12	2,755	3,002	5,226	8,356	21,463	6,252	4,637	4,276	3,668	2,626	11,389	2,938
13	2,970	2,816	6,109	16,221	19,072	5,235	4,844	3,906	1,857	2,617	11,777	2,385
14	2,689	2,967	3,651	11,472	18,994	5,142	4,437	3,695	2,952	2,363	10,962	2,981
15	2,595	2,879	.....	15,989	18,066	4,679	4,289	3,414	3,002	2,388	9,319	2,874
16	2,990	2,193	3,888	46,946	16,696	4,944	4,449	2,566	2,789	2,311	8,426	2,307
17	2,513	2,829	10,129	64,700	17,981	4,549	5,121	3,197	2,336	2,384	7,947	2,272
18	2,736	2,824	3,159	61,270	14,846	4,536	5,125	3,137	2,932	2,016	7,952	1,489
19	1,568	2,758	4,087	57,188	15,227	4,219	4,495	3,178	3,590	2,319	8,130	2,303
20	2,782	2,763	6,699	52,131	13,163	4,710	4,596	3,079	1,733	2,326	7,547	1,870
21	3,000	2,781	12,922	74,469	14,782	5,352	4,391	2,858	4,318	2,352	6,572	2,547
22	2,767	2,771	3,239	60,021	13,215	6,073	4,419	2,747	4,207	4,208	5,222	2,287
23	2,793	2,162	10,025	41,711	3,976	6,655	4,374	2,759	4,147	8,956	3,749	2,047
24	2,542	3,854	7,820	46,693	23,517	6,275	4,258	2,943	3,754	7,804	4,606	1,768
25	2,394	2,812	6,608	40,793	14,220	6,334	4,386	2,990	2,924	7,986	6,185	1,579
26	1,881	2,790	6,637	36,126	4,482	5,817	3,794	2,851	2,969	6,227	6,322	1,506
27	2,499	2,772	7,253	32,729	5,729	5,459	4,215	2,571	2,474	5,388	5,683	1,497
28	2,765	2,558	10,886	30,217	5,117	5,309	3,781	2,410	3,149	2,644	6,169	2,317
29	2,531	2,794	5,945	30,517	4,867	4,200	3,728	2,416	3,148	3,214	8,424	2,063
30	2,473	.....	6,901	30,977	3,192	5,307	3,335	1,625	2,777	2,888	8,432	1,845
31	2,220	.....	5,006	.....	6,092	.....	3,831	2,531	.....	2,891	.....	1,787
Mean	4,304	2,830	13,140	27,400	17,050	5,520	5,330	3,150	3,410	3,768	9,059	2,750

1897.

1	2,073	3,587	2,007	6,334	39,001	18,204	8,719	12,975	4,771	2,314	2,911	4,630
2	2,085	3,485	2,950	7,648	34,299	16,780	9,885	13,656	4,357	2,048	2,637	3,825
3	1,650	3,775	2,423	9,075	32,654	17,526	9,531	11,263	4,340	967	6,687	3,754
4	2,318	3,598	2,629	9,635	34,210	17,542	8,512	9,206	3,701	2,532	9,442	3,190
5	3,732	3,348	2,586	11,536	40,730	17,549	7,147	7,796	3,090	2,490	8,628	3,063
6	18,504	3,223	2,522	12,889	36,362	15,756	8,189	7,226	3,865	2,375	7,729	5,968
7	10,210	4,185	4,026	18,329	24,923	16,023	7,410	5,889	3,571	2,158	6,457	6,382
8	5,860	4,305	2,703	21,149	26,610	15,785	7,922	5,761	4,008	1,533	6,443	5,229
9	5,028	5,634	2,285	18,268	24,400	13,801	7,967	4,000	3,973	2,097	5,195	5,172
10	3,793	6,225	2,291	15,458	23,995	12,961	7,270	5,243	3,997	2,100	7,927	4,879
11	3,293	5,933	4,554	16,671	41,196	16,003	6,290	5,849	4,808	2,109	8,133	4,212
12	3,601	5,007	4,230	14,377	41,223	14,962	5,761	7,562	9,689	1,508	7,313	4,048
13	3,084	4,629	5,238	13,999	23,965	13,819	7,256	9,771	5,463	1,788	6,350	5,765
14	2,542	3,897	5,045	14,796	41,284	15,304	45,507	7,112	4,915	6,070	2,789	6,104
15	2,881	4,070	5,387	16,881	38,988	16,003	55,634	6,601	4,864	6,323	4,902	7,153
16	2,715	4,028	4,925	24,426	32,431	14,617	33,770	5,368	4,325	5,528	4,420	13,621
17	2,187	3,848	2,533	34,813	27,453	14,638	26,160	7,776	4,333	3,837	5,913	14,005
18	2,942	3,163	2,025	28,642	23,788	13,344	21,286	11,566	3,239	3,262	7,191	11,381
19	1,918	2,467	2,304	31,734	21,013	11,200	17,067	8,562	3,632	3,287	6,428	7,665
20	2,211	2,480	2,339	32,799	18,843	11,390	12,542	6,755	3,488	2,322	4,391	5,835
21	2,283	3,543	3,167	26,949	17,562	10,649	7,747	7,129	5,043	2,331	4,161	6,799
22	2,222	2,636	2,083	24,087	15,105	7,399	5,218	7,907	8,422	2,326	3,009	5,419
23	2,951	2,427	2,621	24,008	15,448	9,991	8,408	6,616	7,438	2,051	2,703	3,861
24	2,300	2,302	5,547	29,875	14,809	9,095	8,980	5,718	5,838	1,510	2,181	3,839
25	1,953	2,544	5,832	33,605	10,818	8,353	8,925	5,816	4,481	2,140	2,687	3,225
26	1,847	2,877	6,345	42,860	16,539	8,751	10,826	6,280	3,841	2,348	1,889	2,541
27	2,727	2,825	5,992	51,255	21,779	7,590	9,842	6,220	4,555	2,415	6,097	2,563
28	2,252	3,705	5,311	66,907	24,568	7,691	7,950	5,706	4,084	2,973	13,399	2,685
29	2,477	.....	4,994	58,745	26,000	8,023	6,734	5,382	2,915	2,008	6,883	3,001
30	4,024	.....	5,071	43,797	22,697	8,345	6,405	5,154	2,801	2,344	6,171	2,733
31	3,534	.....	5,513	.....	20,526	.....	11,707	4,364	.....	2,600	.....	2,699
Mean	3,587	3,705	3,790	25,385	26,943	12,970	13,115	7,298	4,595	2,635	5,702	5,330

Daily discharge of Kennebec River at Waterville, Maine, in cubic feet per second, average for the twenty-four hours—Continued.

1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2,475	2,539	4,170	20,385	36,048	14,341	4,385	3,790	.....	.....	.....	.....
2	2,284	2,955	4,188	16,556	39,372	13,776	4,343	2,707	.....	.....	.....	.....
3	2,222	2,687	5,648	13,871	38,301	10,900	3,440	2,887	.....	.....	.....	.....
4	2,715	3,090	5,163	12,143	37,358	8,791	3,490	2,833	.....	.....	.....	.....
5	2,771	2,775	2,997	10,830	37,730	9,846	4,343	2,809	.....	.....	.....	.....
6	3,431	3,068	4,094	10,150	37,569	10,301	4,272	3,712	.....	.....	.....	.....
7	1,807	3,475	5,070	7,080	31,580	9,189	4,477	3,252	.....	.....	.....	.....
8	4,826	2,994	5,033	6,563	29,880	9,098	4,209	4,374	.....	.....	.....	.....
9	5,434	3,744	4,767	7,472	28,753	12,541	5,464	4,218	.....	.....	.....	.....
10	4,492	3,154	4,623	10,457	25,636	14,318	1,745	4,017	.....	.....	.....	.....
11	3,025	3,829	5,329	15,299	22,059	12,086	4,111	3,048	.....	.....	.....	.....
12	3,286	3,317	6,752	19,848	21,899	11,322	4,484	3,413	.....	.....	.....	.....
13	3,240	3,680	8,397	44,854	24,042	11,003	4,267	2,927	.....	.....	.....	.....
14	3,287	3,912	9,880	47,141	34,332	10,777	3,776	1,130	.....	.....	.....	.....
15	4,909	4,026	11,594	50,381	32,988	12,514	4,327	3,443	.....	.....	.....	.....
16	3,717	4,042	12,816	49,415	27,500	11,295	3,994	2,499	.....	.....	.....	.....
17	3,891	3,764	12,215	47,112	24,756	10,584	3,611	2,560	.....	.....	.....	.....
18	3,453	3,221	11,918	47,321	23,440	9,478	3,896	2,491	.....	.....	.....	.....
19	3,460	3,267	12,484	44,700	23,153	9,196	3,938	2,622	.....	.....	.....	.....
20	3,505	2,885	13,218	39,327	20,592	11,129	3,747	2,526	.....	.....	.....	.....
21	3,893	3,172	14,580	36,671	19,088	10,855	3,835	913	.....	.....	.....	.....
22	4,614	3,764	17,177	33,789	18,570	9,950	5,038	3,425	.....	.....	.....	.....
23	2,542	2,133	16,615	30,792	17,073	8,334	3,871	2,866	.....	.....	.....	.....
24	2,321	3,437	15,987	34,352	15,277	9,483	3,418	3,425	.....	.....	.....	.....
25	2,866	4,352	17,812	52,119	15,993	8,864	3,747	2,849	.....	.....	.....	.....
26	2,032	3,933	17,029	45,520	15,589	7,508	3,879	4,432	.....	.....	.....	.....
27	3,136	3,653	16,560	38,083	15,639	5,267	3,385	4,218	.....	.....	.....	.....
28	2,905	4,387	18,928	37,354	14,611	4,326	4,189	3,940	.....	.....	.....	.....
29	2,727	.....	19,762	33,652	16,632	5,689	3,444	3,396	.....	.....	.....	.....
30	1,738	.....	17,711	31,767	16,962	6,715	3,204	3,555	.....	.....	.....	.....
31	2,607	.....	27,432	.....	16,298	.....	2,832	2,857	.....	.....	.....	.....
Mean	3,213	3,402	11,287	29,833	25,120	9,983	3,908	3,133	.....	.....	.....	.....

Daily discharge of Androscoggin River at Rumford Falls, Maine, in cubic feet per second, average for the twenty-four hours.

[Drainage area, 2,320 square miles.]

1892.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	.....	.....	.....	.....	6,500	16,300	3,200	5,860	2,700	2,580	3,830
2	.....	.....	.....	.....	.....	7,000	11,800	3,450	5,860	.....	2,820	3,580
3	.....	.....	.....	.....	.....	5,540	.....	3,450	5,240	2,700	3,060	2,820
4	.....	.....	.....	.....	.....	6,500	16,700	3,450	.....	2,700	4,080	.....
5	.....	.....	.....	.....	.....	6,150	17,500	3,450	4,940	2,940	3,830	3,050
6	.....	.....	.....	.....	.....	6,150	14,800	3,450	4,940	2,940	.....	3,580
7	.....	.....	.....	.....	.....	6,150	12,600	.....	4,350	2,940	2,820	3,580
8	.....	.....	.....	.....	.....	5,540	12,000	3,320	4,080	2,700	3,060	3,830
9	.....	.....	.....	.....	.....	5,540	11,000	2,820	3,580	.....	5,860	3,830
10	.....	.....	.....	.....	.....	4,360	.....	2,820	3,580	2,700	4,650	3,200
11	.....	.....	.....	.....	.....	4,080	10,000	2,600	.....	2,700	3,320	.....
12	.....	.....	.....	.....	.....	4,350	9,300	4,080	3,200	2,700	2,820	3,200
13	.....	.....	.....	.....	.....	3,830	6,500	4,350	3,200	2,700	.....	3,200
14	.....	.....	.....	.....	.....	3,830	6,500	.....	3,200	2,700	2,330	3,200
15	.....	.....	.....	.....	.....	3,830	5,240	5,870	8,000	2,700	2,580	3,200
16	.....	.....	.....	.....	.....	4,080	4,940	5,870	4,940	.....	4,650	2,940
17	.....	.....	.....	.....	.....	3,830	.....	4,940	4,080	2,700	24,500	2,940
18	.....	.....	.....	.....	5,860	4,080	4,650	4,940	.....	2,700	13,000	.....
19	.....	.....	.....	.....	5,550	3,830	3,830	4,350	3,300	2,700	16,300	2,940
20	.....	.....	.....	.....	4,940	4,080	4,080	4,650	3,050	2,700	.....	2,940
21	.....	.....	.....	.....	4,940	11,000	3,700	.....	2,580	2,700	8,300	2,940
22	.....	.....	.....	.....	5,540	11,200	3,700	5,540	3,060	2,700	7,500	2,940
23	.....	.....	.....	.....	7,500	7,500	3,700	4,650	3,830	.....	5,550	2,940
24	.....	.....	.....	.....	11,700	6,500	.....	4,650	3,330	2,940	4,950	2,940
25	.....	.....	.....	.....	9,300	7,000	3,950	4,350	.....	2,940	4,080	.....
26	.....	.....	.....	.....	8,600	13,000	3,950	8,500	3,080	2,940	4,350	.....
27	.....	.....	.....	.....	8,900	11,300	3,580	8,500	3,830	2,940	.....	2,940
28	.....	.....	.....	.....	9,300	15,800	3,320	.....	3,580	2,940	4,350	2,940
29	.....	.....	.....	.....	8,600	19,900	2,820	8,500	3,060	2,940	3,830	3,200
30	.....	.....	.....	.....	8,000	19,900	4,660	8,500	3,060	.....	3,580	3,200
31	.....	.....	.....	.....	8,500	.....	.....	6,500	.....	2,700	.....	3,200
Mean	.....	.....	.....	.....	7,640	7,410	7,330	4,840	4,030	2,780	5,720	3,200

Daily discharge of Androscoggin River at Rumford Falls, Maine, in cubic feet per second, average for the twenty-four hours—Continued.

1893.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	2,990	2,990	2,870	9,560	5,040	3,310	2,840	3,760	.....	3,570	3,820
2	3,580	2,990	2,750	.....	11,460	5,040	.....	2,840	3,260	2,900	3,570	2,860
3	3,580	2,990	2,750	3,250	11,460	4,450	3,310	3,080	.....	2,450	3,340	.....
4	3,830	2,990	2,750	3,250	11,760	.....	3,580	2,840	2,560	2,450	3,340	1,900
5	3,200	.....	.....	2,750	25,460	4,750	3,630	2,580	2,360	2,860	.....	2,260
6	2,940	2,990	2,750	2,750	17,060	4,750	3,580	2,840	2,560	2,660	3,080	2,260
7	2,940	2,990	2,990	2,750	.....	5,040	3,580	3,820	2,760	2,260	3,080	2,860
8	.....	2,990	2,990	2,750	14,260	6,250	3,310	3,820	3,270	.....	3,340	2,460
9	2,940	2,990	2,990	.....	14,260	4,750	.....	2,840	3,530	2,750	3,340	2,460
10	2,940	2,990	2,990	5,910	17,060	5,040	3,310	2,840	.....	2,660	2,870	.....
11	3,200	2,990	2,990	4,700	24,060	.....	3,580	2,580	2,560	2,860	2,670	2,260
12	3,200	.....	.....	5,910	27,860	9,700	2,590	2,580	2,560	2,660	.....	2,060
13	3,200	2,990	3,250	7,050	27,860	8,400	2,590	2,840	3,040	2,660	2,670	2,260
14	3,200	2,990	4,130	7,050	.....	7,100	2,120	2,370	2,350	4,340	2,460	2,260
15	.....	2,990	4,130	8,050	28,460	7,100	2,310	1,960	2,160	.....	2,670	2,460
16	3,200	2,990	3,880	.....	25,060	6,600	.....	1,600	2,570	6,840	2,770	2,460
17	3,200	2,990	3,250	5,000	30,460	5,650	2,310	1,600	.....	3,580	2,770	.....
18	3,200	2,990	3,250	4,700	38,060	.....	2,120	1,750	3,280	4,320	2,770	2,460
19	3,200	.....	.....	4,700	26,060	4,450	2,590	2,580	3,280	3,670	.....	2,460
20	3,200	2,990	3,250	4,400	21,060	5,950	2,590	2,870	2,560	3,080	2,860	2,460
21	3,200	2,990	3,250	5,000	.....	5,100	2,820	3,560	2,560	3,080	2,860	2,460
22	.....	2,990	3,250	5,290	16,760	5,350	2,590	3,060	2,360	.....	3,340	2,260
23	3,200	2,990	3,250	.....	14,260	5,350	.....	3,060	2,160	3,340	3,080	2,260
24	3,200	2,990	2,990	5,590	13,060	5,740	2,590	3,060	.....	4,330	2,680	.....
25	3,200	2,990	2,990	5,910	9,660	.....	2,810	4,080	2,300	13,000	2,060	3,820
26	3,200	.....	.....	5,590	8,860	8,400	3,070	4,850	2,360	6,450	.....	2,860
27	3,200	2,990	3,370	6,550	6,560	6,250	2,590	4,080	3,040	4,320	1,900	3,340
28	2,940	2,990	3,380	7,050	.....	5,640	2,590	3,320	2,150	4,060	2,460	3,080
29	.....	.....	3,110	7,050	5,610	3,680	2,820	3,080	2,350	.....	4,830	3,080
30	2,940	.....	3,370	.....	5,610	3,160	2,330	12,300	2,350	4,830	4,320	3,080
31	2,940	.....	3,060	.....	5,110	.....	2,820	4,850	.....	3,820	.....	.....
Mean	3,180	2,990	3,190	5,030	17,630	5,640	2,800	3,290	2,660	3,830	3,070	2,660

1894.

1	3,570	2,130	1,680	.....	13,730	9,430	.....	1,680	1,980	1,680	7,380	1,880
2	3,570	2,130	1,570	4,290	13,730	9,830	3,110	1,750	.....	1,570	5,060	1,980
3	2,290	1,980	1,570	4,050	14,230	.....	2,280	1,980	1,830	1,730	4,560	1,980
4	2,290	.....	.....	4,050	11,730	9,830	5,310	2,130	1,980	1,980	.....	2,030
5	2,490	2,130	1,980	3,570	10,530	6,730	3,810	.....	1,980	1,680	5,060	2,030
6	2,700	2,130	2,130	3,900	9,730	5,880	3,090	1,380	1,930	1,460	4,050	2,180
7	.....	1,980	3,310	3,570	8,530	5,580	2,280	1,680	1,830	.....	3,300	2,280
8	2,490	2,130	5,880	.....	8,530	5,310	.....	2,030	1,680	1,680	2,890	1,570
9	2,490	2,280	5,310	3,570	7,730	4,810	2,480	2,280	.....	1,780	3,100	.....
10	2,280	2,130	5,310	3,300	7,380	.....	2,700	2,480	3,800	5,580	2,930	1,980
11	2,280	.....	.....	3,570	7,080	4,810	2,480	2,130	2,890	4,050	.....	1,830
12	2,280	2,280	4,550	3,570	5,880	3,100	3,310	.....	1,980	2,890	3,300	2,480
13	2,130	1,680	5,310	3,570	.....	4,060	2,280	1,830	1,630	3,800	2,890	2,890
14	.....	1,980	3,800	3,570	5,070	4,060	2,130	1,980	1,630	.....	2,280	2,730
15	2,280	1,680	4,560	4,300	4,550	3,800	.....	2,130	1,680	3,100	2,730	2,530
16	2,280	2,310	3,800	5,880	4,550	3,800	2,480	2,130	.....	2,690	2,530	.....
17	2,130	1,680	3,570	7,730	5,070	.....	2,280	2,130	1,680	2,890	2,730	2,280
18	2,130	.....	.....	9,030	4,810	4,550	2,480	2,280	1,830	2,890	.....	2,030
19	2,130	1,980	3,570	12,530	4,570	6,170	1,980	.....	2,180	2,530	3,100	2,130
20	3,310	1,980	5,570	17,730	.....	5,310	1,830	2,130	5,880	2,480	1,830	2,730
21	.....	1,980	7,090	22,230	6,170	5,310	3,300	1,980	3,310	.....	1,930	2,330
22	3,310	1,830	5,570	.....	6,170	4,550	.....	1,880	2,480	2,280	2,700	1,460
23	3,310	1,680	5,310	20,630	5,880	3,800	1,980	1,680	.....	2,280	2,700	.....
24	3,570	1,680	4,300	19,230	5,880	.....	1,830	1,680	2,280	2,280	2,890	1,880
25	3,570	.....	.....	18,730	6,470	3,100	1,830	1,730	2,130	2,330	.....	2,030
26	3,310	1,680	4,300	16,530	11,630	3,100	2,130	.....	1,830	2,690	2,490	1,980
27	3,310	1,680	4,050	15,230	.....	3,100	2,130	1,680	1,880	2,130	1,680	1,480
28	.....	1,570	3,800	16,930	5,880	4,050	2,280	1,680	1,830	.....	2,130	1,880
29	2,890	.....	3,570	.....	5,070	4,600	.....	1,880	1,680	2,180	1,460	1,980
30	2,890	.....	3,800	14,930	19,230	4,050	1,830	1,830	.....	2,280	1,380	.....
31	2,280	.....	3,570	.....	10,830	.....	1,680	2,030	.....	.....	.....	1,830
Mean	2,720	2,000	4,030	9,470	8,240	5,090	2,490	1,930	2,220	2,500	3,040	2,090

ver at Rumford Falls, Maine, in cubic feet p
: twenty-four hours—Continued.

1895.

lay.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
,780	5,030	2,010	1,870	.....	6,380	1,730	4,970
,060	.....	2,000	1,980	1,400	3,700	2,160	4,870
,780	4,430	1,950	2,000	1,450	2,570	2,310	5,980
,060	4,350	2,300	.....	1,860	2,570	1,860	2,870
.....	4,010	2,090	1,900	1,710	2,690	1,860	2,850
,350	3,760	1,890	1,860	1,700	.....	1,860	2,810
,330	3,400	.....	1,660	1,840	2,360	2,020	2,830
,570	3,230	2,020	1,640	.....	2,200	2,530	2,880
,770	.....	2,000	1,600	1,550	2,200	2,290	2,400
,880	3,100	1,960	1,760	1,710	2,200	6,440	2,190
,390	2,700	2,010	.....	1,620	2,180	5,190	2,250
.....	2,170	1,920	2,080	2,070	2,020	2,970	2,440
,070	2,060	1,890	2,000	2,130	.....	2,470	1,890
,570	2,380	.....	1,860	1,600	5,130	2,300	1,890
,730	2,580	1,880	1,770	.....	3,980	2,230	2,070
,770	.....	1,840	1,730	1,780	2,770	3,540	1,990
,480	3,000	1,740	1,720	1,620	2,550	3,010	2,260
,700	2,360	1,760	.....	1,530	2,350	2,520	2,220
.....	2,240	1,760	1,990	1,580	2,200	2,800	2,350
,290	2,180	1,690	1,900	1,580	.....	2,600	2,280
,630	2,180	.....	1,760	1,630	2,110	3,970	2,270
,330	2,150	1,490	1,580	.....	1,950	3,060	3,470
,030	.....	1,350	1,590	1,970	1,880	2,340	9,420
,230	2,320	1,350	1,700	2,130	1,830	2,780	5,860
,230	2,330	1,400	.....	2,240	1,880	2,770	4,500
.....	2,320	1,350	2,000	2,370	1,880	2,640	3,250
,000	2,330	1,350	1,880	2,960	.....	15,650	8,460
,730	2,500	.....	1,770	2,910	1,890	7,870	12,420
,730	2,710	1,750	1,860	.....	1,740	5,760	6,970
,530	.....	1,600	1,890	4,790	1,690	5,470	4,030
,330	.....	1,580	1,770	.....	1,640	.....	12,640
,628	2,873	1,775	1,819	1,989	2,539	3,566	4,180

re River at Lambertville, New Jersey, for 1898

ay	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
70	5.70	3.60	3.95	5.15	3.35	5.05	5.40
45	5.30	3.50	4.20	4.70	3.25	4.90	5.20
20	5.05	3.40	5.40	4.50	2.95	4.70	5.05
20	4.90	3.30	4.70	4.35	2.90	4.60	5.00
25	4.75	3.20	5.35	4.25	2.90	4.45	6.85
35	4.60	3.20	6.40	4.25	2.90	4.40	6.30
60	4.40	3.05	6.20	4.25	2.90	4.35	6.10
10	4.40	3.00	5.25	4.25	3.95	4.30	5.75
95	4.30	3.00	4.80	4.55	4.05	4.30	5.45
80	4.20	2.90	4.85	4.60	3.90	4.80	5.45
10	4.10	2.90	6.20	4.35	4.35	5.55	5.00
80	4.15	2.65	5.35	4.15	4.10	7.60	5.15
95	4.00	2.70	4.90	4.05	3.85	7.15	4.80
65	4.00	2.60	4.55	3.95	3.90	6.30	4.95
25	4.55	2.50	4.45	3.80	4.10	5.75	(*a*)
00	4.30	2.50	4.30	3.75	4.60	5.45	(*a*)
60	4.15	2.40	4.10	3.70	5.50	5.30	(*a*)
50	4.00	2.50	4.35	3.65	5.00	5.15	(*a*)
05	3.90	2.60	4.50	3.55	4.70	6.85	4.50
05	3.90	4.20	4.45	3.45	4.60	6.85	4.85
60	3.90	3.70	4.75	3.30	4.50	7.15	4.80
55	4.10	3.70	5.00	3.30	4.60	6.65	4.70
00	4.05	3.30	4.55	3.40	4.65	6.50	5.85
00	3.95	3.10	4.35	3.50	4.80	6.30	5.95
15	3.70	3.00	6.95	3.45	4.70	6.10	6.30
95	3.70	3.20	7.25	3.30	4.70	5.90	5.95
65	3.60	3.40	6.45	3.25	5.20	5.90	5.50
35	3.55	3.40	5.50	3.20	5.90	5.35	5.25
00	3.50	4.20	5.10	3.20	5.95	5.35	4.70
60	3.65	4.20	4.80	3.30	5.45	5.40	4.95
10	.....	4.05	4.60	.....	5.25	.....	4.90

a Frozen.

ıily gage height, in feet, of Susquehanna River at Harrisburg, Pennsylvania, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.66	3.91	4.66	8.66	6.00	4.33	2.00	1.41	2.66	0.75	4.66	3.08
2	2.33	3.41	4.33	7.41	5.41	4.16	2.16	1.50	2.33	.75	4.00	3.16
3	2.16	3.00	4.16	6.41	4.83	3.91	2.00	1.41	3.00	.66	3.66	3.08
4	2.66	2.66	3.91	5.75	4.66	3.58	1.75	2.33	2.50	.66	3.50	3.00
5	1.91	2.66	3.66	5.41	4.41	3.33	1.66	4.58	2.08	.66	3.16	3.66
6	1.91	2.66	3.58	4.91	4.43	3.00	1.58	5.33	1.91	.66	3.90	5.00
7	2.25	2.66	3.50	4.50	4.66	2.83	1.50	4.00	1.66	.66	2.91	4.50
8	2.50	3.08	3.50	4.41	5.50	2.66	1.41	3.50	1.66	1.00	2.50	4.08
9	2.66	3.41	3.33	4.16	6.25	2.50	1.33	3.08	1.66	1.33	2.50	3.83
10	2.75	3.50	3.33	3.83	5.58	2.50	1.25	3.66	2.00	1.41	2.50	3.58
11	3.00	3.41	3.83	3.66	5.16	2.33	1.16	4.25	2.83	2.25	2.58	3.08
12	3.00	3.75	4.91	3.50	4.75	2.33	1.08	3.75	2.75	2.40	4.00	2.50
13	3.33	4.41	6.50	3.33	4.50	2.25	1.00	3.33	2.58	2.33	8.75	2.25
14	4.00	7.66	8.66	3.25	4.00	2.25	.91	2.66	2.08	2.00	8.00	2.25
15	6.95	8.16	9.83	3.16	4.00	2.41	.83	2.50	1.91	2.00	6.58	2.08
16	8.08	7.50	9.33	3.66	4.25	2.75	.83	2.25	1.75	2.08	5.50	2.00
17	7.83	6.50	8.08	4.08	5.16	3.25	.75	2.00	1.41	2.16	4.83	2.00
18	7.58	5.83	7.16	3.91	6.08	3.00	.66	1.91	1.33	3.25	4.33	1.91
19	6.58	5.00	6.33	3.66	5.33	2.66	.66	2.33	1.16	3.75	4.16	2.00
20	5.83	4.33	5.83	3.50	5.50	2.41	.75	3.00	1.00	4.00	4.16	2.50
21	5.75	4.66	7.33	3.41	6.66	2.33	.91	4.41	.91	4.33	4.25	2.91
22	6.16	6.83	9.25	3.33	6.66	2.33	.75	4.33	.91	4.25	4.58	3.08
33	7.41	6.91	10.91	3.16	6.50	2.08	.91	3.75	.91	7.33	4.83	3.50
24	9.25	7.75	15.63	3.00	6.00	2.00	.83	3.41	.83	8.33	4.66	5.41
25	10.50	6.66	15.25	3.50	7.00	2.16	.83	3.00	.83	7.41	4.33	7.83
26	9.50	6.25	11.66	6.66	6.50	2.08	.83	2.66	.75	6.16	4.00	7.66
27	8.00	5.66	9.25	10.33	6.50	2.00	1.33	2.50	.91	5.66	3.91	6.33
28	7.00	5.00	7.75	9.50	6.16	1.91	1.16	2.41	.91	5.58	3.66	5.33
29	6.08	.....	6.66	8.16	5.75	1.83	1.83	4.16	.75	5.66	3.50	4.83
30	5.50	.....	7.00	6.66	5.33	1.66	1.58	3.83	.75	6.08	3.33	4.33
31	4.83	.....	9.00	.....	4.91	.....	1.33	3.00	.....	5.33	.....	3.83

ıily gage height, in feet, of Octoraro Creek at Rowlandsville, Maryland, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.40	3.70	3.60	4.10	3.90	3.90	3.40	3.30	3.30	3.40	3.40	4.60
2	3.60	3.70	3.60	4.00	3.80	3.80	3.30	3.30	3.30	3.40	3.75	4.60
3	3.60	3.70	3.60	3.90	3.80	3.80	3.30	3.40	3.30	3.40	4.55	4.50
4	3.50	3.75	3.60	3.80	3.70	3.70	3.80	5.85	3.30	3.40	4.55	4.75
5	3.45	3.70	3.50	3.80	3.75	3.70	3.70	4.90	3.30	3.40	4.55	9.25
6	3.40	3.70	3.50	3.80	3.80	3.70	3.50	4.35	3.30	3.40	4.90	8.40
7	3.40	3.60	3.50	3.70	4.25	3.70	3.40	3.95	3.45	3.30	4.50	6.70
8	3.40	3.65	3.50	3.70	4.30	3.60	3.40	3.85	3.90	3.30	4.05	5.90
9	3.40	3.65	3.50	3.70	4.05	3.60	3.40	4.00	3.50	3.30	3.90	5.30
10	3.40	3.65	3.50	3.60	3.80	3.60	3.30	4.50	3.50	3.30	3.75	4.90
11	3.40	3.60	3.50	3.60	3.85	3.50	3.30	3.45	3.50	3.40	3.60	3.65
12	3.55	3.50	3.50	3.60	4.25	3.50	3.30	3.80	3.40	3.40	3.50	3.60
13	4.30	3.50	3.50	3.60	4.10	3.50	3.30	3.70	3.40	3.40	3.85	3.60
14	3.60	3.50	3.50	3.50	4.10	3.50	3.30	3.55	3.40	3.40	3.65	3.60
15	4.40	3.50	3.50	3.50	4.25	3.50	3.30	3.50	3.30	3.40	3.60	3.50
16	4.60	3.50	3.50	3.50	5.00	3.50	3.30	3.60	3.30	3.30	3.60	3.50
17	3.85	3.40	3.50	3.50	5.25	3.50	3.30	3.70	3.30	3.30	4.70	3.50
18	3.45	3.45	3.50	3.50	4.95	3.50	3.30	4.50	3.30	3.30	4.90	3.50
19	3.40	3.90	3.50	3.50	4.55	3.50	3.55	4.25	3.30	3.30	6.20	3.90
20	3.75	5.10	3.50	3.50	4.85	4.35	3.55	3.80	3.20	3.30	5.70	9.05
21	3.85	4.60	3.50	3.50	4.90	3.75	3.35	3.50	3.20	3.95	5.15	7.80
22	3.50	3.95	3.60	3.50	4.50	3.70	3.30	3.50	3.20	3.65	4.95	6.05
23	4.30	3.80	3.80	4.30	4.25	3.70	3.30	3.50	4.10	3.50	4.65	6.75
24	3.80	3.80	4.10	4.10	4.20	3.60	3.30	3.50	3.80	3.40	4.70	4.35
25	3.65	3.70	5.10	3.90	4.35	3.60	3.30	6.35	3.60	3.40	4.35	4.30
26	4.00	3.70	3.80	4.05	4.10	3.60	3.30	3.85	3.40	3.40	4.10	4.20
27	3.70	3.60	3.70	4.15	4.80	3.50	3.30	3.70	4.20	3.35	4.90	4.10
28	3.55	3.60	3.70	4.00	4.05	3.50	3.95	3.60	3.90	3.60	4.75	4.00
29	3.50	.....	3.75	4.00	4.00	3.45	3.85	3.45	3.55	3.55	4.80	4.00
30	3.50	.....	4.65	3.90	3.90	3.40	3.45	3.30	3.45	3.50	4.70	3.90
31	3.60	.....	4.30	.....	3.90	.....	3.70	3.30	.....	3.40	.....	4.15

Daily gage heights, in feet, of Potomac River at Williamsport, Maryland, for

Day	Jan.	Feb.	Mar.	Apr.	May	June.	July.	Aug.	Sept.	Oct.	Nov.	D
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
26	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	

[illegible] Bridge have taken up. gage removed December 16 to 31.

Daily gage heights, in feet, of Patuxent River at Laurel, Maryland, for 1

Day	Jan.	Feb.	Mar.	Apr.	May	June.	July.	A
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.90	
2	[illegible]	[illegible]	[illegible]	[illegible]	4.45	4.35	3.90	
3	[illegible]	[illegible]	[illegible]	[illegible]	4.35	4.35	3.90	
4	4.35	[illegible]	[illegible]	[illegible]	4.45	4.35	3.90	
5	4.35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.95	1
6	[illegible]	[illegible]	4.45	[illegible]	[illegible]	4.40	3.65	
7	4.45	[illegible]	4.55	[illegible]	[illegible]	4.35	3.90	
8	[illegible]	[illegible]	4.55	[illegible]	[illegible]	4.35	3.60	
9	4.75	4.90	[illegible]	4.45	[illegible]	4.35	3.55	
10	5.30	4.75	4.55	[illegible]	4.35	4.35	3.55	
11	5.35	4.75	4.55	[illegible]	[illegible]	4.35	3.50	
12	4.95	4.90	4.55	[illegible]	[illegible]	4.15	2.95	----
13	5.00	4.65	[illegible]	4.55	5.35	4.50	3.05	----
14	5.00	4.65	4.55	4.45	5.00	6.00	2.85	----
15	6.00	4.65	[illegible]	4.75	4.50	4.40	3.00	----
16	6.30	4.65	[illegible]	[illegible]	4.60	4.30	3.70	----
17	5.55	4.50	4.70	4.35	5.40	4.25	3.50	----
18	5.35	4.50	4.55	4.45	6.45	4.30	3.60	----
19	5.05	5.35	4.45	4.50	4.35	4.40	3.60	----
20	5.15	5.80	4.25	4.50	4.20	4.20	3.70	----
21	5.50	6.45	4.50	4.45	4.70	4.10	3.75	----
22	5.25	5.75	4.45	4.50	4.55	4.10	3.75	----
23	5.90	5.00	4.35	4.30	4.80	3.95	3.40	----
24	5.10	4.90	4.55	4.40	4.70	3.95	3.15	----
25	5.10	4.85	5.70	4.80	4.50	3.85	3.55	----
26	5.50	4.75	4.50	4.45	4.50	3.95	3.05	----
27	5.50	4.65	4.35	4.35	4.50	3.90	5.85	----
28	5.10	4.85	4.55	4.45	4.45	4.15	5.70	----
29	4.85	----	4.65	4.65	4.10	4.10	3.95	----
30	4.90	----	6.65	4.55	4.55	3.90	3.05	----
31	4.85	----	5.55	----	4.45	----	3.35	----

a Gage torn out; bridge being repair. Station discontinued.

in feet, of Antietam Creek at Sharpsburg, Maryland, for 1898.

Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
40	2.10	2.80	2.00	2.40	1.80	2.00	1.90	1.80	2.10	2.30
60	2.10	2.70	2.00	2.30	1.70	1.90	1.90	1.80	2.10	2.20
90	2.10	2.60	2.00	2.20	1.80	1.80	1.90	1.70	2.00	2.00
50	2.10	2.50	2.00	2.20	1.80	1.90	1.90	1.70	2.10	2.60
40	2.20	2.60	2.10	2.10	1.80	2.50	2.10	1.70	1.90	7.80
20	2.10	2.50	2.20	2.20	1.80	2.00	2.00	1.60	1.80	3.85
40	2.10	2.50	2.20	2.20	1.70	1.80	1.90	1.70	1.80	3.25
20	2.10	2.40	2.40	2.10	1.70	1.80	1.90	1.60	1.70	3.00
0	2.00	2.40	3.25	2.10	1.80	2.00	1.90	1.60	1.70	2.90
0	2.00	2.40	2.70	2.10	1.80	3.10	1.80	1.60	1.90	2.80
0	2.10	2.40	2.50	2.10	1.80	3.05	1.70	1.60	2.50	2.70
0	2.10	2.30	2.40	2.15	1.80	2.30	1.90	1.80	2.15	2.70
0	2.00	2.30	2.50	2.20	1.80	2.10	1.80	1.70	2.20	2.70
0	2.00	2.30	2.30	2.20	1.80	2.00	1.80	1.80	2.20	2.80
0	2.00	2.30	2.30	2.10	1.80	2.05	1.90	1.70	2.00	2.70
0	2.10	2.35	2.90	2.10	1.70	2.00	1.80	1.50	2.00	2.80
0	2.00	2.40	3.00	2.10	1.70	2.00	1.80	1.60	1.90	2.50
0	2.20	2.30	2.80	2.10	1.80	5.05	1.70	2.75	2.00	2.40
0	2.20	2.30	2.60	2.00	1.80	3.65	1.90	1.80	2.60	2.50
0	2.20	2.30	2.40	2.10	1.80	2.95	1.80	2.40	2.50	3.15
0	2.20	2.30	2.40	2.00	1.80	2.45	1.80	2.20	2.40	2.90
0	2.00	2.20	2.10	1.90	1.80	2.30	1.80	2.90	2.40	2.80
0	2.10	2.20	2.50	2.10	1.80	2.10	1.90	2.80	2.30	3.85
0	2.50	2.20	3.00	2.10	1.80	2.00	1.90	1.90	2.40	3.20
0	2.55	2.20	2.70	1.90	2.20	1.90	1.80	1.70	2.30	3.00
0	2.70	2.30	2.90	1.90	1.90	2.00	1.80	2.40	2.30	2.90
0	2.25	2.30	2.70	1.90	1.90	2.00	1.90	2.30	2.30	2.80
0	2.95	2.20	2.70	1.80	1.80	1.90	1.80	2.10	2.30	2.60
0	2.80	2.20	2.60	1.80	1.80	2.00	1.90	2.10	2.20	2.60
0	2.70	2.20	2.50	1.80	1.80	2.00	1.80	2.10	2.20	2.50
0	2.75	2.10	2.40	.....	1.90	2.00	.....	2.10	.....	2.60
0	3.10	.....	.....							
0	2.90	.....	.....							

in feet, of North River at Port Republic, Virginia, for 1898.

Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
2.10	3.85	2.65	2.35	2.20	4.25	2.60	2.40	3.00	2.40
2.10	3.50	2.60	2.30	2.20	4.25	2.50	2.40	2.80	2.30
2.10	3.30	2.50	2.15	2.20	4.00	2.50	2.40	2.65	2.30
2.10	3.15	2.45	2.15	2.20	4.50	2.50	2.40	2.60	3.00
2.10	3.00	2.40	2.15	2.20	8.00	2.50	3.00	2.60	7.00
2.10	2.90	3.00	2.10	2.20	5.00	2.50	2.90	2.60	5.00
2.10	2.90	6.40	2.10	2.20	5.00	2.50	2.80	2.50	3.60
2.10	2.90	7.25	2.10	2.20	4.60	2.50	2.60	2.50	3.30
2.10	2.80	6.30	2.10	2.20	4.00	2.50	2.40	2.45	3.00
2.10	2.60	5.00	2.00	2.15	9.00	2.50	2.25	2.40	2.90
2.10	2.75	4.00	2.00	2.10	9.00	2.50	2.10	2.40	2.80
2.10	2.75	3.60	2.60	2.10	7.00	2.50	2.10	2.40	2.70
2.10	2.75	3.30	2.50	2.00	6.00	2.50	2.10	2.35	2.65
2.10	2.75	3.20	2.35	2.00	6.00	2.50	2.00	2.35	2.60
2.10	2.75	3.00	2.20	2.10	6.00	2.50	2.00	2.30	2.55
2.10	4.15	2.80	4.20	2.10	4.50	2.50	2.00	2.30	2.50
2.10	5.20	2.80	3.40	2.25	4.20	2.50	2.00	2.25	2.50
2.10	4.50	2.70	3.00	2.50	4.00	2.50	2.00	2.20	2.40
2.25	4.00	2.60	3.00	2.40	4.00	2.50	9.50	2.15	2.30
2.80	3.50	2.60	3.00	2.30	3.60	2.50	5.00	2.60	2.30
2.95	3.20	2.60	3.00	2.30	3.30	2.50	5.00	2.60	2.30
2.85	3.00	3.35	2.90	2.30	3.20	2.50	10.00	2.60	2.30
2.75	2.90	3.30	2.80	2.30	3.10	2.75	6.50	2.60	4.00
2.75	2.75	3.20	2.65	3.00	3.10	2.75	5.00	2.60	4.30
2.75	2.75	3.00	2.50	2.80	3.00	2.65	3.80	2.60	3.60
2.85	2.75	2.90	2.50	2.70	2.90	2.65	3.65	2.60	3.30
2.90	2.75	2.75	2.50	3.50	2.80	2.60	3.50	2.55	3.00
3.00	2.75	2.75	2.40	4.75	2.70	2.60	3.30	2.50	2.80
3.00	2.70	2.65	2.40	5.00	2.70	2.50	3.15	2.50	2.60
3.00	2.65	2.50	2.40	5.00	2.60	2.40	3.15	2.50	2.60
3.00	2.65	2.40	.....	4.50	2.60	2.40	3.15	.....	2.60
3.30	2.65	.....							
4.20	.....								

Daily gage height, in feet, of South River at Port Republic, Virginia, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.80	2.00	1.50	2.25	2.10	1.75	1.60	2.10	1.60	1.35	2.50	1.90
2	1.80	2.00	1.50	2.25	2.05	1.65	1.60	2.00	1.50	1.35	2.35	1.80
3	1.80	2.00	1.60	2.25	2.00	1.60	1.55	2.00	1.50	1.35	2.20	1.80
4	1.75	2.00	1.60	2.20	2.00	1.60	1.55	2.00	1.50	1.35	2.15	2.50
5	1.75	2.00	1.60	2.15	1.90	1.60	1.55	4.40	1.50	1.75	2.10	4.00
6	1.65	1.95	1.60	2.15	2.20	1.60	1.55	3.00	1.50	3.00	2.10	3.00
7	1.65	1.90	1.60	2.15	4.10	1.60	1.55	2.40	1.50	2.90	2.05	2.90
8	1.60	1.85	1.60	2.10	5.00	1.60	1.55	2.40	1.50	2.60	2.00	2.70
9	1.60	1.80	1.60	2.00	4.10	1.55	1.55	2.30	1.50	2.30	2.00	2.50
10	1.60	1.75	1.60	2.10	3.50	1.55	1.50	6.40	1.50	2.15	2.00	2.40
11	1.60	1.70	1.60	2.05	3.10	1.50	1.45	6.60	1.50	2.00	2.00	2.35
12	1.55	1.70	1.60	2.00	2.90	1.85	1.40	3.60	1.50	1.95	2.00	2.30
13	1.55	1.65	1.60	2.00	2.60	1.75	1.40	3.00	1.50	1.90	2.00	2.30
14	1.55	1.60	1.60	2.00	2.60	1.65	1.40	3.00	1.50	1.80	1.90	2.25
15	1.55	1.55	1.60	2.75	2.50	1.55	1.60	2.80	1.50	1.80	1.90	2.20
16	1.55	1.50	1.60	3.00	2.40	1.75	1.60	2.60	1.50	1.80	1.90	2.15
17	1.55	1.50	1.85	2.80	2.40	1.75	1.60	2.40	1.50	1.75	1.90	2.10
18	1.55	1.50	1.85	2.70	2.30	1.75	1.60	2.30	1.50	1.75	1.85	2.10
19	1.55	1.50	1.85	2.50	2.20	1.75	1.60	2.30	1.50	7.50	1.85	2.10
20	1.55	1.50	1.80	2.40	2.10	1.75	1.60	2.20	1.50	3.80	2.15	2.00
21	1.55	1.50	1.80	2.25	2.00	1.75	1.60	2.20	1.50	3.80	2.10	2.00
22	1.55	1.50	1.80	2.15	2.60	1.75	1.60	2.20	1.50	7.60	2.10	2.00
23	2.00	1.50	1.80	2.10	2.00	1.70	1.60	2.20	1.65	4.50	2.10	2.60
24	2.00	1.50	1.90	2.10	2.00	1.70	1.70	2.10	1.65	4.00	2.10	2.60
25	2.00	1.50	1.90	2.20	1.90	1.70	1.70	2.00	1.60	3.10	2.10	2.50
26	2.00	1.50	1.90	2.50	1.90	1.70	1.70	1.90	1.50	3.00	2.10	2.45
27	2.00	1.50	2.00	2.30	1.85	1.65	1.70	1.80	1.45	2.80	2.10	2.40
28	2.00	1.50	2.00	2.25	1.80	1.60	1.70	1.70	1.40	2.60	2.10	2.35
29	2.00	.....	2.00	2.20	1.80	1.60	1.70	1.60	1.35	2.50	2.10	2.30
30	2.00	.....	2.00	2.10	1.80	1.60	1.70	1.60	1.35	2.50	2.00	2.30
31	2.00	.....	2.20	.....	1.80	.....	2.10	1.60	.....	2.50	.....	2.30

Daily gage height, in feet, of Shenandoah River at Millville, West Virginia, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.10	1.60	0.60	3.50	1.80	1.40	0.70	1.70	1.50	0.90	2.80	2.10
2	.80	1.60	.60	3.40	1.70	1.30	.....	.90	1.50	.90	2.40	2.10
3	.70	1.30	.60	2.70	1.50	1.20	.70	.70	1.70	1.00	2.50	2.10
4	.90	1.20	.60	2.50	1.40	1.10	.70	1.00	1.50	1.00	2.70	2.50
5	.50	1.60	.50	2.30	1.20	1.10	.60	3.20	1.40	1.20	2.10	5.40
6	.70	1.10	.60	2.10	1.20	1.10	.60	7.90	1.40	1.80	2.00	6.00
7	.50	1.40	.60	2.00	1.60	1.00	.50	3.70	1.40	1.50	2.00	4.60
8	.90	1.40	.60	1.90	5.90	.90	.50	1.50	1.40	1.10	1.90	3.80
9	.50	1.20	.60	1.80	8.50	.80	.50	3.50	1.30	1.50	1.90	3.00
10	.70	.90	.50	1.60	7.00	.70	.50	6.20	1.30	1.40	1.80	2.80
11	1.20	.90	.50	1.40	5.00	.70	.60	11.70	1.10	1.30	1.90	2.60
12	.80	.90	.50	1.30	4.00	.70	.70	9.60	1.10	1.20	1.80	2.40
13	1.60	.70	.50	1.30	3.30	.60	.70	5.60	1.10	1.00	1.70	2.40
14	1.50	.70	.50	1.30	2.90	1.00	.70	4.70	1.10	1.00	1.80	2.20
15	1.60	.70	.50	1.80	2.50	1.00	.70	3.70	1.00	1.00	1.70	1.90
16	3.20	.60	.50	4.10	2.40	1.00	.70	3.50	1.00	1.00	1.70	2.20
17	2.50	.50	.70	5.20	2.30	.90	.70	3.60	1.00	1.10	1.70	2.20
18	2.20	.50	1.90	4.00	2.00	1.00	.70	3.40	1.10	1.10	1.70	2.20
19	1.70	.60	1.60	3.40	1.80	1.50	.60	2.80	1.00	7.75	1.80	2.30
20	1.70	.60	1.70	3.00	1.70	1.40	.50	3.40	1.00	8.40	2.30	2.00
21	1.70	.60	1.70	2.40	1.60	1.10	.70	2.70	1.00	5.00	2.70	2.00
22	1.60	.90	1.60	2.20	1.60	1.30	.70	2.40	1.00	5.00	2.50	2.00
23	1.60	.90	1.50	2.00	2.00	1.00	.60	2.30	1.10	9.10	2.50	2.30
24	1.70	.90	1.50	1.80	2.50	1.00	.50	2.10	1.10	5.70	2.50	2.90
25	1.70	.80	2.50	1.70	3.00	1.10	1.20	2.00	1.10	4.40	2.30	4.00
26	1.80	.80	2.70	1.70	2.50	.80	1.10	2.00	1.40	3.50	2.30	3.50
27	2.20	.70	2.50	1.70	2.00	.70	1.10	1.60	1.20	3.40	2.20	3.00
28	2.00	.70	2.20	1.90	2.00	.70	1.00	1.80	1.10	2.20	2.00	2.80
29	1.80	.....	2.20	1.80	2.00	.70	1.00	1.60	1.10	3.00	2.00	2.50
30	1.10	.....	2.50	1.80	1.70	.70	1.20	1.60	1.00	2.90	2.20	2.40
31	1.40	.....	3.00	.....	1.50	.....	1.70	1.60	.....	2.90	.....	2.30

Daily gage height, in feet, of Monocacy River at Frederick, Maryland, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	5.25	5.40	5.40	7.10	4.70	5.50	4.40	4.70	4.00	3.80	5.50	6.30
2	5.20	6.50	5.30	6.90	4.70	5.40	4.30	4.60	4.00	3.80	5.30	6.20
3	6.00	6.50	5.30	6.00	4.60	5.30	4.30	4.40	4.00	3.80	4.70	5.50
4	5.70	6.50	5.70	5.80	4.60	5.20	4.30	4.10	4.00	3.80	4.60	7.00
5	5.50	6.10	6.20	5.80	4.60	5.10	4.40	7.65	3.90	3.80	4.50	17.95
6	5.50	6.10	6.00	5.80	4.60	5.10	4.40	6.90	3.90	3.80	4.40	8.50
7	5.50	5.50	5.90	5.80	6.20	5.10	4.40	5.10	3.90	3.80	4.40	7.00
8	5.60	5.00	5.50	5.50	7.00	5.00	4.40	4.20	4.00	3.90	4.40	6.40
9	5.70	5.20	5.30	5.50	13.40	5.00	4.40	4.10	4.00	3.90	4.40	5.70
10	6.50	5.40	5.20	5.20	7.50	5.00	4.40	6.70	4.00	3.80	4.70	5.50
11	7.10	5.40	5.20	5.20	6.50	5.00	4.30	12.40	3.90	3.80	9.70	5.30
12	7.20	6.00	5.10	5.20	6.50	5.00	4.20	6.00	3.80	3.90	6.90	5.30
13	8.10	6.20	5.10	5.10	8.20	5.00	4.20	5.40	3.80	3.80	5.40	5.30
14	8.50	5.60	5.10	5.10	6.00	4.90	4.20	5.40	3.80	3.80	5.30	5.30
15	11.90	5.50	5.00	5.30	5.60	4.90	4.20	4.60	3.80	4.00	5.20	5.20
16	11.40	5.30	5.00	5.90	6.75	4.90	4.10	4.50	3.80	4.20	5.00	5.00
17	8.75	5.20	5.00	5.50	11.55	4.70	4.10	4.50	3.80	3.90	5.50	5.00
18	7.50	5.10	5.00	5.00	7.50	4.60	4.10	6.35	3.80	5.50	6.10	5.00
19	6.90	6.40	5.00	4.90	6.50	4.50	4.10	10.10	3.80	6.25	12.35	6.00
20	6.90	6.50	4.90	4.90	6.50	4.50	4.30	7.00	3.80	5.60	9.50	9.60
21	9.00	14.80	6.10	4.90	6.40	4.50	5.40	5.50	3.80	4.90	6.85	8.60
22	9.50	12.00	7.30	4.80	6.00	4.50	4.40	4.90	3.90	11.55	5.90	8.80
23	12.75	7.50	7.60	4.80	6.00	4.50	4.10	4.60	4.15	9.00	5.90	13.60
24	9.50	6.50	7.60	5.00	6.60	4.40	4.00	4.50	4.20	7.10	6.30	8.00
25	7.50	6.30	10.75	5.30	6.70	4.40	3.90	4.40	4.10	5.20	5.90	7.50
26	8.70	5.70	8.50	5.30	6.60	4.40	3.90	4.30	3.90	5.20	5.40	6.10
27	8.00	5.60	6.60	5.00	6.30	4.40	4.30	4.30	3.90	5.50	5.20	6.00
28	7.30	5.40	6.60	4.90	5.90	4.40	4.30	4.20	3.90	5.30	5.20	5.90
29	6.50	.....	7.70	4.90	5.80	4.40	4.30	4.10	3.90	5.10	5.30	5.50
30	5.90	.....	9.50	4.80	5.70	4.40	4.20	4.10	3.80	5.10	5.70	5.50
31	5.70	.....	7.90	.....	5.60	.....	4.00	4.00	.....	6.00	.....	5.50

aily gage height, in feet, of Potomac River at Point of Rocks, Maryland, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.90	2.80	1.90	6.10	2.60	2.20	0.90	1.50	1.20	0.70	2.70	2.10
2	2.90	1.70	1.80	5.20	2.40	2.00	.80	1.70	1.10	.70	2.50	2.10
3	3.00	2.00	1.70	4.60	2.20	1.80	.80	1.40	1.10	.60	2.30	2.00
4	3.20	1.90	1.70	4.10	2.00	1.70	.70	1.20	1.00	.70	2.20	2.50
5	3.20	1.90	1.60	3.80	1.90	1.60	.70	2.20	1.00	.80	2.00	5.10
6	3.30	2.00	1.60	3.60	1.80	1.40	.70	7.20	1.00	.80	1.80	9.20
7	3.20	2.00	1.60	3.20	2.20	1.30	.70	6.10	1.10	1.00	1.80	6.10
8	2.90	1.90	1.50	2.90	5.40	1.30	.80	3.70	1.00	1.10	1.70	4.50
9	3.00	1.90	1.50	2.40	11.05	1.20	.70	3.90	1.00	1.00	1.60	3.60
10	3.20	1.80	1.40	2.50	9.60	1.20	.70	5.60	.90	1.00	1.60	3.00
11	3.90	1.80	1.40	2.50	6.50	1.10	.70	14.00	.90	.90	2.00	2.60
12	5.80	1.90	1.50	2.40	5.20	1.10	.60	16.05	.90	.90	1.80	2.40
13	5.70	2.00	1.50	2.40	4.20	1.10	.50	9.50	.80	1.40	1.80	2.20
14	5.30	1.90	1.60	2.50	3.70	1.30	.50	8.00	.80	1.20	2.00	2.20
15	5.50	1.90	1.60	2.50	3.10	1.30	.50	7.20	.80	1.00	2.00	2.00
16	6.70	2.00	1.70	4.00	3.00	1.30	.50	6.10	.80	.80	1.80	1.80
17	8.00	2.00	1.70	9.00	3.20	1.30	.50	5.20	.80	.80	1.80	1.80
18	6.70	1.80	2.00	6.70	4.60	1.20	.50	4.30	.80	.80	1.80	2.00
19	5.60	1.70	5.80	5.10	4.40	1.50	.70	3.30	.80	1.40	2.20	2.10
20	4.90	1.70	4.60	4.20	3.50	1.40	.70	3.10	.70	9.00	3.00	2.20
21	4.70	2.80	3.50	3.50	2.30	1.30	.90	3.00	.70	5.40	3.60	2.60
22	4.60	3.80	3.50	3.20	2.90	1.30	.90	3.80	.70	5.35	3.30	3.30
23	5.00	4.10	6.60	2.90	3.10	1.30	1.10	2.80	.70	13.10	3.20	4.70
24	9.40	3.40	6.20	2.60	3.90	1.20	.90	2.30	.70	10.10	3.10	6.20
25	8.40	2.90	6.40	2.60	5.10	1.10	.80	2.00	.70	5.90	3.00	6.90
26	5.10	2.60	10.50	2.60	5.60	1.10	.90	1.80	.70	4.50	2.70	5.30
27	5.00	2.30	7.20	2.50	4.10	1.00	1.20	1.50	.90	3.80	2.60	4.30
28	5.10	2.10	5.30	3.30	3.40	1.00	1.00	1.50	.80	3.60	2.40	3.70
29	5.10	.....	4.40	3.00	3.00	.90	1.20	1.40	.70	3.40	2.20	3.20
30	3.60	.....	4.30	2.80	2.80	.90	1.40	1.30	.70	3.00	2.10	3.00
31	3.40	.....	6.20	.....	2.40	.....	1.70	1.30	.....	2.80	.....	2.70

Daily gage height, in feet, of Rock Creek at Park station, District of Columbia for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.10	3.15	3.10	3.30	3.50	2.95	2.85	2.80	2.45	2.30	2.80	2.95
2	2.95	3.15	3.10	3.20	3.50	2.95	2.80	2.80	2.40	2.35	2.65	2.80
3	3.10	3.10	3.10	3.20	3.50	2.95	2.80	2.80	2.40	2.35	2.60	2.80
4	3.05	3.10	3.15	3.10	3.00	2.90	2.80	2.80	2.40	2.40	2.60	3.15
5	3.05	3.05	3.15	3.20	3.50	2.90	2.85	3.90	2.40	2.40	2.60	4.45
6	3.00	3.05	3.10	3.15	3.20	2.90	2.85	2.85	2.40	2.40	2.65	3.15
7	3.05	3.05	3.10	3.10	3.95	2.90	2.80	2.80	2.40	2.40	2.65	3.00
8	3.05	3.05	3.10	3.10	3.40	2.90	2.80	2.80	2.35	2.35	2.60	2.90
9	3.05	3.10	3.05	3.10	3.30	2.90	2.80	2.90	2.35	2.35	2.60	2.85
10	3.90	3.10	3.05	3.10	3.00	2.90	2.80	3.45	2.35	2.35	2.65	2.85
11	3.35	3.10	3.05	3.05	3.00	2.90	2.80	3.70	2.35	2.35	3.40	2.75
12	3.20	3.10	3.05	3.15	3.15	2.90	2.75	4.00	2.30	2.40	3.85	2.80
13	3.30	3.10	3.05	3.15	3.15	2.90	2.75	4.15	2.30	2.40	2.70	2.85
14	3.20	3.05	3.05	3.15	3.15	3.20	2.75	3.95	2.30	2.45	2.65	2.80
15	3.40	3.05	3.05	3.15	3.10	2.90	2.80	2.75	2.30	2.40	2.65	2.80
16	4.10	3.05	3.05	3.10	3.10	2.85	2.80	2.80	2.30	2.45	2.65	2.80
17	3.30	3.00	3.25	3.10	3.90	2.85	2.75	2.55	2.30	2.45	2.80	2.75
18	3.25	3.05	3.20	3.10	3.10	2.85	2.75	2.55	2.30	2.40	3.25	2.75
19	3.15	3.25	3.10	3.60	3.10	2.90	2.95	3.15	2.30	2.90	4.05	2.80
20	3.20	3.50	3.10	3.20	3.10	2.85	2.90	2.75	2.30	2.75	3.10	3.35
21	3.35	3.75	3.05	3.30	3.30	2.85	2.90	2.75	2.25	2.60	2.85	3.35
22	3.20	3.40	3.05	3.30	3.50	2.85	2.80	2.70	2.30	2.75	2.80	2.90
23	3.25	3.25	3.05	3.30	3.50	2.80	2.75	2.60	2.45	2.90	2.80	3.60
24	3.30	3.20	3.10	3.10	3.50	2.80	2.75	2.60	2.60	2.70	2.80	3.05
25	3.15	3.15	3.50	3.15	3.65	2.80	2.75	2.55	2.35	2.65	2.75	2.90
26	3.65	3.10	3.20	3.10	3.50	2.80	2.75	2.55	2.35	2.55	2.80	2.80
27	3.40	3.10	3.10	3.65	3.50	2.80	3.10	2.50	2.30	2.60	2.75	2.80
28	3.25	3.10	3.10	3.10	2.00	3.10	3.10	2.50	2.30	2.60	2.75	2.80
29	3.15	.....	3.15	3.10	3.00	2.95	3.00	2.50	2.30	2.60	2.80	2.70
30	3.15	.....	3.95	3.10	2.95	2.90	2.80	2.50	2.30	2.85	2.85	2.75
31	3.15	.....	3.45	.....	2.95	.....	2.80	2.45	.....	2.95	.....	2.85

Daily gage height, in feet, of North of James River at Glasgow, Virginia, for 1898

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.28	2.00	1.55	3.09	2.00	2.00	1.45	1.30	1.28	1.19	2.80	1.86
2	1.30	1.60	1.55	3.04	1.90	1.90	1.45	1.30	1.25	1.20	2.60	1.75
3	1.32	1.75	1.55	2.92	1.88	1.80	1.46	1.28	1.20	1.21	2.50	1.72
4	1.50	1.70	1.65	2.75	1.88	1.76	1.45	1.74	1.45	1.30	2.30	1.82
5	1.50	1.70	1.75	2.70	1.89	1.68	1.45	6.25	1.70	1.80	2.20	4.30
6	1.45	1.70	1.75	2.68	5.90	1.65	1.50	3.60	1.48	2.40	2.05	3.50
7	1.52	1.65	1.80	2.55	5.88	1.62	1.40	2.88	1.25	2.00	2.02	2.90
8	1.60	1.60	1.80	2.45	4.50	1.58	1.40	2.76	1.15	1.80	1.90	2.50
9	1.50	1.50	1.82	2.40	3.90	1.60	1.40	2.55	1.14	1.65	1.80	2.30
10	1.85	1.50	1.81	2.35	3.80	1.62	1.35	5.75	1.11	1.52	1.82	2.10
11	2.15	1.50	1.80	2.35	3.30	1.62	1.32	8.95	1.08	1.48	1.85	2.15
12	1.65	1.45	1.81	2.35	3.10	1.63	1.32	4.45	1.04	1.60	1.88	2.20
13	1.50	1.55	1.83	2.35	2.77	1.80	1.33	3.40	1.00	1.50	1.85	1.93
14	1.40	1.45	1.85	2.75	2.60	1.92	1.35	3.00	1.00	1.40	1.82	1.70
15	1.55	1.50	1.89	4.48	2.48	1.95	1.35	2.80	1.05	1.40	1.84	1.62
16	3.60	1.30	1.82	4.10	2.38	2.00	1.35	2.40	1.00	1.40	1.86	1.62
17	2.90	1.20	1.86	3.75	2.32	2.05	1.35	2.25	1.00	1.40	1.88	1.72
18	2.52	1.35	1.95	3.15	2.21	2.05	3.00	2.15	1.02	1.38	1.90	1.70
19	2.30	1.50	2.00	3.00	2.10	2.40	2.50	2.00	1.00	5.80	2.40	1.65
20	2.15	1.50	1.95	2.85	2.01	2.55	2.15	1.90	.95	3.65	3.20	1.75
21	2.45	1.70	1.80	2.65	2.27	2.25	1.90	1.70	.98	3.00	2.80	1.70
22	1.40	1.80	1.75	2.32	2.55	2.00	1.70	1.64	1.00	10.75	2.52	1.68
23	1.45	1.90	1.75	2.30	2.85	1.90	2.52	1.52	3.00	5.60	2.50	3.05
24	1.42	1.75	2.14	2.25	2.77	1.80	1.90	1.70	1.90	3.90	2.41	3.40
25	2.00	1.75	2.85	2.28	3.10	1.70	1.90	1.50	1.48	3.60	2.30	2.80
26	2.50	1.70	2.80	2.25	2.70	1.65	1.90	1.48	1.30	2.95	2.18	2.60
27	2.50	1.65	2.58	2.25	2.90	1.60	1.90	1.45	1.25	2.15	2.10	2.42
28	2.45	1.55	2.50	2.12	2.55	1.60	2.00	1.42	1.20	2.50	2.00	2.30
29	2.20	.....	2.08	2.10	2.32	1.58	2.00	1.38	1.20	2.60	1.90	2.12
30	2.20	.....	4.85	2.05	2.25	1.50	1.80	1.30	1.20	2.80	1.92	2.02
31	2.10	.....	4.50	.....	2.10	.....	1.60	1.30	.....	2.90	.....	2.00

gage height, in feet, of James River at Buchanan, Virginia, for 1898.

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
2.50	3.00	2.50	6.95	3.00	3.00	1.90	2.45	2.40	2.20	3.65	3.20
2.55	3.00	2.50	5.70	2.90	2.85	1.90	2.20	2.30	2.10	3.55	3.10
2.70	2.90	2.60	4.85	2.80	2.70	1.90	2.29	2.20	2.10	3.25	3.00
2.60	2.90	2.60	4.40	2.70	2.60	1.90	3.60	2.50	2.60	3.00	3.30
2.50	2.80	2.50	4.20	2.60	2.60	1.80	7.30	2.25	2.75	3.00	5.45
2.50	2.80	2.50	4.35	4.35	2.60	1.85	5.55	2.20	4.35	3.00	4.45
2.40	2.80	2.50	4.15	11.10	2.50	1.90	4.20	2.20	3.95	2.90	4.40
2.40	2.80	2.60	3.90	8.80	2.40	1.90	3.95	2.10	3.20	2.90	3.70
2.40	2.70	2.60	3.80	7.00	2.40	1.90	4.50	2.10	2.95	2.80	3.70
2.40	2.70	2.60	3.80	5.70	2.30	1.90	8.30	2.00	2.70	2.70	3.60
3.50	2.55	2.60	4.70	4.95	2.30	1.90	11.55	2.00	2.50	2.70	3.50
3.95	2.40	2.60	6.65	4.45	2.30	1.90	6.90	2.00	2.60	2.70	3.40
3.55	2.40	2.60	5.50	4.05	2.30	1.80	5.05	1.90	2.50	2.70	3.30
3.20	2.40	2.60	5.40	3.75	2.30	1.80	6.00	1.90	2.50	2.90	3.20
3.15	2.40	2.60	7.20	3.60	2.30	1.80	4.70	1.90	2.40	2.90	3.10
4.20	2.40	2.60	6.35	3.50	2.30	1.80	4.10	1.80	2.40	2.90	3.00
4.80	2.30	2.60	5.50	3.50	2.40	1.80	3.60	1.80	2.45	2.90	3.00
4.30	2.30	3.55	4.90	3.30	2.40	2.35	3.35	1.80	2.70	2.90	2.90
3.70	2.30	4.40	4.40	3.30	2.55	2.50	3.35	1.80	6.45	4.25	2.90
3.55	2.30	4.20	4.15	3.50	2.70	2.20	3.05	1.80	4.85	6.30	2.90
3.80	2.30	3.75	3.75	3.30	2.60	2.10	2.80	1.80	6.85	5.25	2.80
3.85	2.75	3.45	3.55	3.10	2.50	2.30	2.70	2.25	14.10	4.40	2.80
3.55	3.30	3.25	3.35	5.00	2.40	2.35	2.55	5.50	8.60	4.25	4.35
3.50	3.05	3.10	3.30	5.90	2.40	2.30	2.40	3.70	6.05	4.20	5.60
3.70	2.90	4.00	3.30	5.05	2.30	2.50	2.65	3.00	5.00	4.05	4.70
3.80	2.80	5.25	3.30	4.70	2.30	2.30	2.50	2.50	4.55	3.75	4.25
4.45	2.70	4.45	3.30	4.25	2.15	2.25	2.50	2.40	4.10	3.55	3.85
4.10	2.60	4.00	3.25	3.80	2.05	3.40	2.50	2.30	4.00	3.40	3.60
3.70	.....	4.30	3.10	3.45	2.00	3.25	2.50	2.30	3.65	3.30	3.50
3.55	.....	8.50	3.00	3.30	2.00	2.75	2.50	2.20	3.70	3.20	3.50
3.25	.....	8.20	.....	3.20	.....	2.50	2.40	.....	3.90	.....	3.40

List of discharge measurements, 1898.

Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
			Feet.	*Sec.-feet.*
Delaware River	Lambertville, N. J	E. G. Paul	7.85	44,421
do	do	do	3.30	4,683
Susquehanna River.	Harrisburg, Pa	do	6.58	76,250
do	do	do	15.75	250,485
do	do	do	14.65	223,374
do	do	do	10.75	149,589
do	do	do	.83	5,466
do	do	do	.92	6,993
do	do	do	.72	6,121
Octoraro Creek	Rowlandsville, Md	Hugh W. Caldwell	3.40	201
do	do	do	4.00	430
do	do	do	3.70	360
do	do	do	4.90	934
do	do	do	4.10	428
do	do	do	3.90	339
do	do	do	3.60	236
do	do	do	4.10	416
do	do	do	3.70	362
do	do	do	4.30	426
do	do	do	3.50	214
do	do	do	4.10	424
do	do	do	3.30	211
do	do	do	3.80	288
do	do	do	3.40	225
do	do	do	3.80	289
do	do	do	6.40	1,663
do	do	do	3.50	209
do	do	E. G. Paul	3.60	182
do	do	Hugh W. Caldwell	3.30	200
do	do	do	3.70	287
do	do	do	4.10	420
do	do	do	6.40	1,557
do	do	do	4.20	434
Patapsco River	Woodstock, Md	E. G. Paul	4.55	763
do	do	do	3.60	190
Patuxent River	Laurel, Md	do	5.80	359
do	do	do	4.90	221
Antietam Creek	Sharpsburg, Md	do	2.70	427
do	do	do	3.50	831
Shenandoah River	Millville, W. Va	do	2.20	3,001

List of discharge measurements, 1904—Continued.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
				Feet.	*Sec.-feet.*
Aug. 24	Shenandoah River	Millville, W. Va.	E. G. Paul	4.30	7,834
Oct. [illegible]	do	do	do	.90	1,001
Jan. 28	Monocacy River	Frederick, Md.	do	7.35	2,352
Aug. 31	do	do	do	6.95	1,605
Jan. 25	Potomac River	Point of Rocks, Md.	do	6.50	31,344
Aug. 29	do	do	do	3.30	14,309
Oct. 3	do	do	do	.65	1,939
May 24	Rock Creek	Park station, D. C.	do	3.20	95
May [illegible]	North River	Glasgow, Va.	D. C. Humphreys	6.00	6,316
July 19	do	do	do	1.60	436
Dec. 28	do	do	do	3.68	2,869
Feb. 12	James River	Buchanan, Va.	do	2.40	932
June 27	do	do	do	2.05	544
July 30	do	do	do	2.86	1,468
Dec. 23	do	do	do	4.32	3,664
May 12	North Branch of Potomac River	Cumberland, Md.	E. G. Paul	2.80	1,829
Do.	Wills Creek	do	do		381
May 13	do	do	do	5.00	368
Oct. 2	Antietam Creek	Stonebraker's Mills, Md.	do	1.80	70
Oct. 3	Great Gunpowder River	One-half mile above Lavasky, Md.	do		308

Rating tables.

Lamberville.		Harrisburg.		Rockhandsville.		Woodstock.		Laurel.		Sharpsburg.	
Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
2.4	2,500	[illegible]	3,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	1.2	28
2.6	2,750	[illegible]	4,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.3	45
2.8	3,250	[illegible]	5,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.9	5	1.4	60
3.0	3,750	1.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.0	10	1.5	80
3.2	4,350	2.0	13,900	[illegible]	[illegible]	3.4	122	3.2	20	1.6	105
3.4	5,250	2.5	18,300	3.4	[illegible]	[illegible]	[illegible]	3.4	30	1.7	138
3.6	6,300	3.0	23,400	3.6	[illegible]	[illegible]	173	3.6	42	1.8	171
3.8	7,450	3.5	29,100	3.8	330	[illegible]	200	3.8	56	1.9	202
4.0	8,800	4.0	35,400	4.0	390	[illegible]	235	4.0	70	2.0	233
4.2	10,300	4.5	42,750	4.2	450	3.9	270	4.2	86	2.1	264
4.4	11,900	5.0	51,400	4.4	520	4.0	310	4.4	102	2.2	294
4.6	13,600	5.5	61,000	4.6	596	4.1	355	4.6	120	2.3	325
4.8	15,400	6.0	69,900	4.8	815	4.2	400	4.8	140	2.4	356
5.0	17,200	6.5	78,800	5.0	930	4.3	450	5.0	162	2.5	387
5.2	19,050	7.0	87,700	5.2	1,040	4.4	520	5.5	217	2.6	417
5.4	20,950	7.5	96,600	5.4	1,155	4.5	590	6.0	272	2.7	448
5.6	22,860	8.0	105,500	5.6	1,265	4.6	670	6.5	329	2.8	479
5.8	24,780	8.5	114,400	5.8	1,380	4.7	750	7.0	389	2.9	510
6.0	26,700	9.0	123,300	6.0	1,490	4.8	835	7.5	455	3.0	540
6.2	28,620	9.5	132,250	6.2	1,605	4.9	915	8.0	545	3.2	646
6.4	30,540	10.0	141,240	6.4	1,715	5.0	1,000	8.5	655	3.4	768
6.6	32,460	10.5	150,190	6.6	1,830	5.1	1,100	9.0	800	3.6	887
6.8	34,380	11.0	159,140	6.8	1,940	5.2	1,200	9.5	1,025	3.8	1,009
7.0	36,300	11.5	168,090	7.0	2,055	5.3	1,300	10.0	1,400	4.0	1,114
7.5	41,100	12.0	177,040	7.5	2,335	5.4	1,400	10.5	2,034	4.2	1,227
8.0	45,900	12.5	185,990	8.0	2,615	5.5	1,500	11.0	2,674	4.4	1,340
8.5	50,700	13.0	194,940	8.5	2,900	5.6	1,600			4.6	1,454
9.0	55,500	13.5	203,890	9.0	3,180	5.7	1,700			4.8	1,567
9.5	60,300	14.0	212,840	9.5	3,460	5.8	1,800			5.0	1,680
10.0	65,100	15.0	230,740	10.0	3,740	5.9	1,900				

Rating tables—Continued.

Port Republic. *a*		Port Republic. *b*		Millville.		Frederick.		Point of Rocks.	
Gage height	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1.6	165	1.3	95	0.3	600	3.6	45	0.0	300
1.8	215	1.4	105	.4	620	3.8	90	.2	600
2.0	275	1.5	120	.5	650	4.0	150	.4	1,100
2.2	350	1.6	140	.6	710	4.2	210	.6	1,700
2.4	445	1.7	160	.7	780	4.4	270	.8	2,400
2.6	555	1.8	180	.8	850	4.6	340	1.0	3,100
2.8	700	1.9	210	.9	920	4.8	420	1.2	4,000
3.0	865	2.0	250	1.0	990	5.0	500	1.4	4,900
3.2	1,050	2.2	350	1.2	1,160	5.5	750	1.6	5,800
3.4	1,290	2.4	495	1.4	1,390	6.0	1,020	1.8	6,700
3.6	1,550	2.6	645	1.6	1,650	6.5	1,450	2.0	7,600
3.8	1,860	2.8	795	1.8	1,960	7.0	1,880	2.2	8,600
4.0	2,170	3.0	945	2.0	2,310	7.5	2,310	2.4	9,600
4.2	2,480	3.2	1,090	2.2	2,700	8.0	2,740	2.6	10,650
4.4	2,790	3.4	1,240	2.4	3,100	8.5	3,170	2.8	11,750
4.6	3,100	3.6	1,390	2.6	3,500	9.0	3,600	3.0	12,850
4.8	3,410	3.8	1,535	2.8	3,930	9.5	4,030	3.5	15,500
5.0	3,720	4.0	1,685	3.0	4,370	10.0	4,460	4.0	18,250
5.5	4,495	4.2	1,835	3.2	4,840	10.5	4,890	4.5	21,250
6.0	5,270	4.4	1,980	3.4	5,320	11.0	5,320	5.0	24,050
6.5	6,045	4.6	2,125	3.6	5,800	11.5	5,750	5.5	27,000
7.0	6,820	4.8	2,275	3.8	6,280	12.0	6,180	6.0	30,150
7.5	7,595	5.0	2,425	4.0	6,800	12.5	6,610	6.5	33,200
8.0	8,370	5.2	2,575	4.5	8,200	13.0	7,040	7.0	37,700
8.5	9,145	5.4	2,720	5.0	9,830	13.5	7,470	7.5	42,200
9.0	9,920	5.6	2,870	5.5	11,605	14.0	7,900	8.0	46,700
9.5	10,695	5.8	3,015	6.0	13,430	14.5	8,330	8.5	51,200
10.0	11,470	6.0	3,165	6.5	15,255	15.0	8,760	9.0	55,700
10.5	12,245	6.5	3,535	7.0	17,080	15.5	9,190	9.5	60,200
11.0	13,020	7.0	3,905	.....	.....	16.0	9,620	10.0	64,700

a Rating table for North River, applicable from August 5, 1895, to December 31, 1898.
b Rating table for South River, applicable from August 5, 1895, to December 31, 1898

SOUTHERN ATLANTIC COAST DRAINAGE.

DESCRIPTION OF RIVER STATIONS.

Roanoke station on Roanoke River.—Described on page 25 of Paper No. 15; results for 1897 shown on page 174 of the Nineteenth Annual Report, Part IV. The observer since September 3, 1898, has been Preston Lyons.

Clarksville station on Dan and Staunton rivers.—Described on page 26 of Paper No. 15; results for 1897 shown on page 176 of the Nineteenth Annual Report, Part IV. This station was discontinued on February 26, 1898.

Neal station on Roanoke River.—Described on page 28 of Paper No. 15; results for 1897 given on page 174 of the Nineteenth Annual Report, Part IV.

Tarboro station on Tar River.—Described on page 29 of Paper No. 15; results for 1897 given on page 183 of the Nineteenth Annual Report, Part IV.

Selma station on Neuse River.—Described on page 30 of Paper No. 15; results for 1897 given on page 185 of the Nineteenth Annual Report, Part IV.

Moncure station on Haw River.—This station, established May 6, 1898, is located about 1¾ miles north of Moncure, Chatham County, North Carolina, at the bridge of the Seaboard Air Line, which crosses the river here, and about 2 miles from the junction with the Deep

River to form the Cape Fear. The observer is M. A. Moore, Moncure Chatham County, North Carolina, who also attends the station o Deep River. The gage is a horizontal rod, well painted, divided int feet and tenths, and securely nailed to the outer side of the guard rai of the bridge on the upstream side. The two-foot mark on the ro is over the center of the second-floor beam from the south end of th second span from the south end of the bridge. The outer rim o the pulley wheel is 0.3 foot from the zero of the gage rod and the dis tance from the end of the weight to the pointer on the wire rope i 43.45 feet, the gage reading zero when the weight touches the botton of the stream. The initial point for soundings is a notch cut in th guard rail opposite the south end of the bridge and on the upstrean side, the section here being better than that on the downstream side The channel is straight for some distance above and below the statio The velocity is good and uniformly distributed across the stream. Bot banks are rather low and somewhat subject to overflow in time o flood. The bed of the stream is of coarse sand and gravel, and is prob ably not subject to any decided change in high water. The curren here is somewhat modified by a fish dam about 150 yards above th bridge. The station is reached by private conveyance from Moncure

Moncure station on Deep River.—This station, established May 5 1898, is located about one-fourth of a mile south of Moncure, Chathan County, North Carolina, at the covered wooden bridge of the Seaboar Air Line, which crosses the river here, and about 2 miles above th junction with the Haw River to form the Cape Fear. The observer i M. A. Moore, Moncure, Chatham County, North Carolina, a farme and also bridge watchman, living about 100 yards from the bridge The gage is a horizontal rod, well painted, divided into feet and tenths and securely nailed to the guard rail of the bridge. The zero of th rod is 50 feet south of the north end of the second span of the bridg from the north. The outer rim of the pulley wheel is 3.7 feet from th zero of the rod, and from the end of the weight to the pointer on th wire rope is 45.16 feet, the gage reading zero when the weight touche the bottom of the river. The initial point for soundings is a note cut in the guard rail opposite the south end of the bridge and on th downstream side. The channel is straight for some distance abov and below the station. The velocity is not great but sufficient fo the purpose, and is well distributed across the stream. Both bank are rather low and subject to overflow. The bed of the river is c fine sand and mud, and is probably subject to change in high wate

Fayetteville station on Cape Fear River.—Described on page 31 c Paper No. 15; results for 1897 given on page 187 of the Nineteent Annual Report, Part IV.

Salisbury station on Yadkin River.—Described on page 32 of Pape No. 15; results for 1897 given on page 194 of the Nineteenth Annu Report, Part IV.

Norwood station on Yadkin (Pedee) River.—Described on page 3 of Paper No. 15; results for 1897 given on page 194 of the Nineteent *Annual Report, Part IV.*

Catawba station on Catawba River.—Described on page 34 of Paper No. 15; results for 1897 shown on page 204 of the Nineteenth Annual Report, Part IV. The observer since July 2, 1898, has been C. A. Reid, jr.

Rockhill station on Catawba River.—Described on page 35 of Paper No. 15; results for 1897 shown on page 204 of the Nineteenth Annual Report, Part IV. The rating table for this station, printed on page 213 of the above report, does not fairly represent the conditions prevailing from February to December, 1897. The drought that began in August of that year and continued until the latter half of October was the most severe in the history of the State, if not in the history of the South generally, and the streams attained a lower stage of flow than ever before, according to the testimony of those living near them. Also the level of the underground waters, as shown by the wells and springs, was lower than for a quarter of a century. As shown by the gage heights of the rivers, all of them during September and October of this year reached a stage of flow lower than at any time during the year or during the preceding years. The rating table and the gage heights for the upper station on this river show that the minimum flow for this year was during this period. It therefore appears that the same should be true for this lower station, but instead the rating table makes the minimum flow for the year come in January, which is out of accord not only with the abnormal conditions prevailing at this time, but with those of the normal year.

Gaffney station on Broad River (a tributary of Santee River).—This station has been changed from the locality described on page 36 of Paper No. 15. The gage wire was broken on October 1, 1898, and on October 25 the gage was moved to Gaffney Ferry, about 200 yards above the railroad bridge, where there is a better section and where nearly all the measurements have been taken. The gage was moved in the following manner: A small temporary gage was set up at the ferry in order that the rise or fall of the river might be determined and allowed for in the final setting of the gage in its new position. The wire to the gage at the railroad bridge was then replaced and the gage reading taken. The rod was then removed and taken to the ferry. The temporary gage was read again and with the same result as before, indicating that the water was at a stand. This being the case, all that was necessary to set the gage was to make the reading in its new position the same as in its old position. From the fact, however, that in its old position the water had frequently fallen below the zero of the gage, it was thought best to change the position of the rod somewhat, and accordingly the zero of the rod was moved downward 2 feet. The reading at the bridge was 0.90 foot; the new reading was therefore 2.90 feet. The observations from January 1 to September 30 have been adjusted to the new zero by adding 2 feet.

The rod is securely nailed and braced to a large overhanging tree just east of Gaffney Ferry, on the south side of the river, and the rod *is 72 feet west of a bench* mark consisting of a large steel nail

driven in a notch cut in the root of a large elm tree on the south side of the river, just to the east of the road leading to the ferry and about 30 feet from the river bank. The zero of the rod is 13.29 feet below this nail. The bottom here is sand, with some mud, and quite smooth. The velocity is quite rapid, well distributed all the way across, and the channel is straight for some distance above and below the station. The services of the ferryman, John W. Gaffney, Gaffney, South Carolina, were obtained to take charge of the gage.

Alston station on Broad River (tributary to Santee River).—Described on page 37 of Paper No. 15; results for 1897 shown on page 215 of the Nineteenth Annual Report, Part IV.

Waterloo station on Saluda River.—Described on page 38 of Paper No. 15; results for 1897 shown on page 221 of the Nineteenth Annual Report, Part IV.

Madison station on Tugalo River.—Established July 19, 1898, at Cooks Ferry, about half a mile from Madison, South Carolina, and 1 mile below the Southern Railway bridge on Tugalo River. S. C. Cobb, a farmer living in Georgia, about 300 yards from the ferry, was employed on July 19, 1898, as observer; but the discharge measurements were begun on May 26, 1898. The gage is a 2 by 4 inch scantling, 10 feet long, graduated to feet and tenths, and nailed to a sycamore tree on the right bank at the ferry landing. Higher stages are noted on the sycamore above the rod by measuring up from the top of rod. Measurements are made from a boat held in place by the ferry rope stretched across the river. The bench marks are on the left bank of river, the first being on a willow tree at the bateau landing, and consisting of three large nails 3 feet above zero of gage; the second is on the same tree, being one nail 6 feet above zero of gage; and the third is a large nail in a sycamore at the ferry landing 12 feet above the zero of gage.

Calhoun Falls station on Savannah River.—Described on page 39 of Paper No. 15; results for 1897 are shown on page 223 of the Nineteenth Annual Report, Part IV. The station was discontinued on August 9, 1898.

Augusta station on Savannah River.—Observations of river height have been maintained since 1875 by the city of Augusta at the city highway bridge. The results have been printed in the volumes entitled Stages of Water at River Stations, prepared by the United States Weather Bureau. Those for 1875 to 1889 are given in Part III, those for 1890 to 1892 in Part IV, and for 1893 to 1895 in Part V. The gage consists of a vertical timber fastened to the pier and graduated to feet and inches. Readings are made four times a day, usually at 6 a. m. 12 m., 6 p. m., and 9 p. m. The 6 a. m. readings are those used by the Weather Bureau. The observer is J. M. Youngblood, keeper of the city bridge. The gage heights as given in the following pages have been changed from feet and inches to feet and tenths, and have been averaged for the day. The zero of this gage is the low water of 1835 *The highest water recorded* was on September 11, 1888, at 38.7 feet

ıat time the entire city was submerged, ten persons were drowned, ›roperty was damaged to the amount of $2,000,000.[1]

ɜ floods of this river have been investigated under the direction › Corps of Engineers, United States Army, and reports prepared ›orge W. Brown, assistant engineer. The first of these, dated ıary 11, 1889, was printed, with maps, as House Ex. Doc. No. 213, first Congress, first session; also given, with few maps, in the rt of the Chief of Engineers, United States Army, 1890, page 1340. ɜr report, dated June 10, 1890, also prepared by Mr. George W. n, was printed as Ex. Doc. No. 255, Fifty-first Congress, second ›n. In this report is given a rating table, showing the probable arge of the river at heights on the gage of from 5 to 40 feet. On 17 of this latter document is shown the run-off in cubic feet per d per square mile for various portions of the drainage basin. › is also given a table of distances and elevations and the slope of ver, as well as a description of the character of the drainage basin. ›m the figures in the above-named reports a computation was by Cyrus C. Babb of the fluctuations of flow of Savannah River, ›sults being published in the Fourteenth Annual Report, Part II, ɜ United States Geological Survey, page 147, and relating to the › 1884 to 1891, inclusive. A discussion of the results is also given ansactions American Society of Civil Engineers, Volume XXIII, 332. The later discharge measurements, made during 1897 and by Prof. B. M. Hall and others, have furnished material for the ıruction of a new rating table. A comparison of this with earlier, ıccurate tables may be of interest in this connection.

Rating tables of Savannah River at Augusta, Georgia.

Gage height.	Discharge in second-feet.		
	Brown. *a*	Babb. *b*	Hall. *c*
Feet.			
4.0	.....	1,900	2,350
5.0	3,000	2,700	3,100
6.0	4,000	3,600	4,020
7.0	5,210	4,900	5,400
8.0	6,600	6,700	7,200
9.0	8,400	8,500	9,340
10.0	10,400	10,400	11,800
11.0	12,600	12,800	14,620
12.0	14,900	14,800	17,750
13.0	17,300	17,300	21,100
14.0	20,000	20,100	25,000
15.0	22,700	22,800	29,300
16.0	25,500	25,300	33,600
17.0	28,700	28,500	38,000
18.0	32,100	31,900	42,400
20.0	39,000	39,000	51,200
22.0	.....	46,800	60,000
24.0	.....	55,000	68,800
26.0	.....	62,700	77,600
28.0	.....	76,500	86,400
30.0	89,000	89,200	.....

George W. Brown, assistant engineer, Corps of Engineers, United States Army, pub- n Annual Report of Chief of Engineers, United States Army, 1890, page 1341.

Cyrus C. Babb, assistant hydrographer, United States Geological Survey. Results pub- n Fourteenth Annual Report of United States Geological Survey, Part II, page 147.

B. M. Hall, resident hydrographer, United States Geological Survey, from gagings made and 1898.

[1] *Description of River Gages*, Part V, United States Weather Bureau, p. viii.

Much of the difference between the results given in the above tables is due to deepening of the channel at the Augusta wharf, immediately below the city bridge, to a pier of which the gage is attached.

By the use of the values of discharge corresponding to various gage heights Professor Hall has computed the minimum flow, by months, from 1892 to 1898, inclusive. In each case he has taken the average of all the readings for the day of lowest water in the given month, and not the lowest single reading. The lowest average daily reading for the seven years is that on July 3, 1898, of 3.88. The rating table, therefore, begins at about this point, the value for a height of 3.9 feet being 2,306 second-feet.

Minimum monthly gage height and discharge of the Savannah River at Augusta, Georgia, for 1892 to 1898, inclusive.

Date.	Gage height.	Discharge.
1892.		
	Feet.	*Sec.-feet.*
January 2	7.80	6,820
February 7	8.55	8,328
March 6	8.25	7,698
April 30	8.63	8,502
May 2	7.30	5,922
June 30	7.53	6,358
July 17	6.76	5,033
August 10	6.06	4,091
September 21	6.40	4,522
October 2	6.30	4,589
November 2	6.80	5,002
December 15	6.63	4,843
1893.		
January 18	6.45	4,591
February 10	8.06	7,318
March 31	8.00	7,200
April 20	6.30	4,589
May 29	6.35	4,455
June 30	6.70	4,944
July 15	5.53	3,550
August 26	5.23	3,296
September 26	6.86	5,200
October 31	6.06	4,091
November 21	5.73	3,735
December 15	6.30	4,589
1894.		
January 6	7.10	5,572
February 4	7.76	6,760
March 31	8.13	7,456
April 28	7.23	5,810
May 31	6.36	4,484
June 18	5.33	3,380
July 16	5.23	3,296
August 24	5.90	3,910
September 13	5.30	3,352
October 31	5.83	3,840
November 12	5.76	3,765
December 3	5.53	3,550
1895.		
January 8	7.75	6,728
February 10	8.66	8,506
March 1	8.95	9,220
April 7	8.76	8,800
May 18	8.70	8,656
June 27	6.73	5,040
1895—Continued.		
	Feet.	*Sec.-feet.*
July 21	6.66	5,905
August 3	5.90	3,910
September 30	5.40	3,436
October 26	5.03	3,125
November 2	5.20	3,268
December 8	5.40	3,436
1896.		
January 15	6.50	4,660
February 28	8.10	7,396
March 31	7.50	6,274
April 24	6.03	4,040
May 23	5.30	3,352
June 18	4.93	3,045
July 4	4.73	2,875
August 25	5.16	3,200
September 23	4.10	2,405
October 11	3.94	2,323
November 1	4.80	2,930
December 27	6.16	4,158
1897.		
January 12	6.00	4,020
February 1	7.40	6,098
March 6	9.20	9,804
April 29	8.60	8,436
May 29	6.60	4,800
June 27	6.00	4,020
July 4	5.65	3,655
August 31	5.40	3,436
September 15	4.55	2,738
October 10	3.93	2,330
November 14	5.00	3,100
December 12	5.85	3,860
1898.		
January 11	5.97	3,930
February 26	5.67	3,885
March 27	5.67	3,670
April 23	6.97	5,350
May 29	4.92	3,032
June 11	4.20	2,475
July 3	3.88	2,294
August 4	6.55	4,730
September 30	7.47	6,220
October 2	7.02	5,435
November 6	7.55	6,364
December 18	7.85	6,916

Each of the above gage heights is an average of all the readings taken on the day named.

Water is diverted from Savannah River above the city of Augusta by a canal following along the right bank, described in Volume XVI of the Tenth Census, 1880, on page 789. A conception of the size of this canal is given by a measurement made by Prof. B. M. Hall on September 29, 1897, above all the water wheels. At that time he found a flow of 2,640 second-feet. Presumably all of this was passing through the water wheels under varying heads. The full head is 50 feet, but the canal has three levels. Some of the wheels discharge from the upper level or main canal directly into the river, while others discharge from one level to another.

The measurements noted on page 44 were made at North Augusta highway bridge, which is a through iron bridge in three spans, 206½ feet, 209 feet, and 206½ feet in length, respectively, not including approaches from street to each end. There are two piers in the water and one in each bank. The stream at gage height, 6.67, is 572 feet wide, including the two piers, has a maximum depth of 10 feet and an average depth of 6.5 feet, the mean velocity being 1.24 feet per second. The initial point is center of first sidewalk floor beam, right bank, downstream side of bridge.

Carlton station on Broad River (tributary to Savannah River).—Described on page 40 of Paper No. 15; results for 1897 shown on page 225 of the Nineteenth Annual Report, Part IV.

Cary station on Oconee River.—Described on page 41 of Paper No. 15; results for 1897 shown on page 227 of the Nineteenth Annual Report, Part IV. This station was discontinued March 31, 1898, as the rating is evidently affected by a dam several miles below.

Dublin station on Oconee River.—Described on page 42 of Paper No. 15; results for 1897 shown on page 227 of the Nineteenth Annual Report, Part IV. Observations were taken under the direction of the United States Geological Survey from February 11 to October 15, inclusive, with Jasper Young as observer. Since that time the United States Weather Bureau has taken the observations, the observer being Mathew R. Scarborough. The measurements are taken on the upstream side of the iron highway bridge, which is about 100 yards above the railroad bridge at which the gage is located.

Almon station on Yellow River.—Described on page 43 of Paper No. 15; result for 1897 shown on page 229 of the Nineteeth Annual Report, Part IV. No current meter measurements have been made during 1898, nor have gage heights been recorded. An attempt, however, has been made to ascertain the fluctuations of discharge by comparison with the observations made at Macon. A rating table published on page 229 of the Nineteenth Annual Report, Part IV, was constructed from discharge measurements made during the autumn of 1897. This has been used to obtain the quantity of flow at fifteen times on days when the elevation was not fluctuating notably. The gage height at Macon, Georgia, was ascertained on each morn-

ing following these dates. In this way the estimated discharge at Almon was referred to the readings on the gage at Macon and a new discharge table computed in which the heights at Macon are given and assume discharges at Almon are set opposite. The application of such a table involves the assumption that the fluctuations at Almon are coincident with those at Macon. The following values have been obtained:

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
−1.00	80	3.00	528	7.00	1,070	10.00	1,478	14.00	2,022
0.00	132	4.00	664	8.00	1,206	11.00	1,614	16.00	2,294
1.00	257	5.00	800	9.00	1,342	12.00	1,750	18.00	2,566
2.00	392	6.00	935						

Macon station on Ocmulgee River.—Described on page 44 of Paper No. 15; result for 1897 shown on page 230 of the Nineteenth Annual Report, Part IV.

TABLES OF DAILY GAGE HEIGHT.

Daily gage height, in feet, of Roanoke River at Roanoke, Virginia, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.15	2.00	0.95	2.25	0.80	1.35	0.95	1.85	1.05	1.30	1.85	1.30
2	1.15	1.90	.95	2.00	.75	1.30	.90	1.90	.95	1.40	1.80	1.20
3	1.15	1.85	1.00	1.85	.75	1.20	.85	1.95	.95	2.08	1.75	1.50
4	1.10	1.85	1.00	1.70	.70	1.15	.85	2.50	1.05	2.00	1.75	2.00
5	1.10	1.80	1.10	1.65	.70	1.10	.85	3.10	2.04	2.68	1.70	3.40
6	1.00	1.80	1.00	1.60	3.80	1.05	.85	2.45	2.00	3.00	1.75	2.50
7	.95	1.70	.95	1.60	4.90	1.05	.80	1.95	2.03	2.35	1.70	2.25
8	.95	1.65	.95	1.50	3.25	1.00	.75	1.90	1.07	2.00	1.70	2.00
9	.90	1.60	.90	1.50	2.50	1.00	.60	1.90	1.07	1.90	1.65	1.90
10	.90	1.60	.85	1.40	2.10	.95	.55	1.95	1.07	1.80	1.65	1.60
11	.85	1.55	.80	1.40	2.00	.90	.45	1.95	1.07	1.70	1.60	1.50
12	.85	1.50	.75	1.35	2.20	.90	.45	1.90	1.05	1.65	1.60	1.50
13	.85	1.50	.75	1.30	1.65	.95	.45	1.90	1.03	1.60	1.55	1.50
14	.95	1.40	.75	1.65	1.50	1.00	.45	2.60	1.01	1.55	1.50	1.45
15	1.30	1.35	.70	1.60	1.45	1.25	.50	2.45	1.01	1.50	1.45	1.40
16	1.40	1.30	.70	1.55	1.45	1.30	.50	2.20	1.01	1.50	1.40	1.35
17	1.35	1.20	.70	(a)	1.40	1.40	.45	1.90	1.50	1.40	1.55	1.65
18	1.25	1.15	.65	(a)	1.30	1.40	1.15	1.75	1.00	1.60	1.50	1.65
19	1.20	1.10	.65	(a)	1.25	1.50	1.20	1.50	1.00	3.50	1.95	1.65
20	1.15	1.10	.65	(a)	1.20	1.45	1.10	1.30	1.00	2.60	2.20	1.60
21	2.00	1.00	.65	(a)	1.15	1.40	.95	1.25	1.05	2.60	2.00	1.60
22	2.50	1.00	.60	(a)	1.55	1.60	1.75	1.20	1.40	5.00	1.90	1.55
23	2.35	1.00	.60	(a)	3.10	1.70	1.75	1.10	3.55	4.45	1.85	2.80
24	2.35	.95	.70	(a)	2.95	1.60	1.60	1.10	2.20	3.00	1.75	2.50
25	2.40	.95	1.50	(a)	2.40	1.55	1.45	1.00	1.85	2.75	1.65	2.35
26	2.40	.95	1.75	(a)	1.95	1.50	1.25	.95	1.70	2.30	1.65	2.20
27	2.35	.90	2.00	(a)	1.62	1.35	1.15	.95	1.50	2.00	1.50	2.00
28	2.20	.90	2.50	(a)	1.50	1.15	1.35	1.10	1.50	1.90	1.40	1.90
29	2.15	.....	2.75	(a)	1.45	1.00	1.40	1.10	1.40	1.90	1.50	1.85
30	2.15	.....	3.05	(a)	1.40	1.00	1.55	1.15	1.30	1.95	1.40	1.80
31	2.15	.....	2.75	(a)	1.40	.....	1.55	1.15	.....	1.95	.....	1.80

a April 17–30, no observations.

Daily gage height, in feet, of Dan River at Clarksville, Virginia, for 1898. (*a*)

Day.	Jan.	Feb.	Day.	Jan.	Feb.	Day.	Jan.	Feb.	Day.	Jan.	Feb.
1	0.70	0.87	9	1.00	0.90	17	0.75	0.55	25	2.70	1.02
2	.68	.72	10	.80	1.25	18	1.45	.53	26	3.92	.95
3	.65	.69	11	.70	1.12	19	1.05	.59	27	2.45	.....
4	.78	.65	12	1.10	1.02	20	.95	.55	28	2.05	.....
5	.95	.58	13	.89	.88	21	.80	.68	29	1.70	.....
6	1.05	.55	14	.89	.76	22	.74	.75	30	1.28	.....
7	1.00	.62	15	.70	.70	23	.68	.88	31	.95	.....
8	1.00	.75	16	.65	.60	24	1.25	.95			

a Station discontinued February 26.

Daily gage height, in feet, of Staunton River at Clarksville, Virginia, for 1898. (*a*)

Day.	Jan.	Feb.	Day.	Jan.	Feb.	Day.	Jan.	Feb.	Day.	Jan.	Feb.
1	0.35	0.49	9	0.60	0.51	17	0.48	0.27	25	2.10	0.74
2	.43	.40	10	.42	.65	18	1.05	.25	26	3.25	.65
3	.39	.43	11	.38	.60	19	.70	.33	27	2.08	.....
4	.50	.39	12	.69	.54	20	.65	.33	28	1.63	.....
5	.65	.33	13	.50	.51	21	.42	.43	29	1.25	.....
6	.70	.27	14	.50	.49	22	.47	.48	30	.88	.....
7	.71	.35	15	.38	.38	23	.43	.54	31	.65	.....
8	.71	.48	16	.39	.34	24	.65	.65			

a Station discontinued February 26.

Daily gage height, in feet, of Roanoke River at Neal, North Carolina, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	8.60	8.60	3.40	10.00	6.10	11.20	3.20	7.80	5.30	13.50	16.80	7.50
2	7.40	7.30	3.50	15.30	5.40	9.80	3.60	7.20	5.30	11.00	17.30	8.10
3	6.40	6.70	3.40	15.20	4.70	8.60	3.40	6.70	4.80	9.10	15.00	8.30
4	5.70	5.80	3.50	12.80	4.30	7.10	2.70	6.20	3.80	7.50	12.30	9.00
5	4.80	4.90	4.30	10.60	4.00	5.67	1.90	5.30	3.30	6.10	10.10	10.50
6	4.20	4.10	7.40	9.90	4.30	4.40	1.85	4.50	2.70	5.40	8.50	15.70
7	4.00	3.60	9.70	13.00	6.70	3.80	4.20	3.50	2.30	5.80	7.70	20.90
8	4.40	4.00	9.20	15.40	15.95	3.30	4.20	5.65	7.50	12.80	6.90	20.10
9	4.60	4.40	8.10	14.30	20.85	3.00	3.90	6.90	8.90	13.00	6.80	17.50
10	4.60	4.80	6.90	11.50	22.51	2.90	5.30	5.90	8.60	10.40	6.70	14.80
11	4.43	4.90	6.00	9.80	22.51	2.70	5.90	4.70	7.90	8.10	6.20	12.70
12	4.50	4.80	5.40	8.30	20.00	2.30	5.90	4.10	5.50	6.40	5.70	10.90
13	4.68	4.70	4.90	7.30	16.95	2.20	4.80	4.60	3.80	5.30	5.30	9.50
14	4.80	4.70	4.80	7.40	14.20	2.10	5.15	5.30	2.60	4.60	5.30	8.50
15	4.80	4.40	5.00	8.40	12.10	2.40	4.40	9.20	2.10	4.20	5.50	7.70
16	4.85	4.20	5.00	7.90	11.32	4.20	3.30	11.70	1.80	3.80	5.40	7.10
17	4.90	3.90	4.80	7.80	12.50	6.90	2.50	15.70	1.60	3.50	5.50	6.50
18	4.60	3.70	4.60	8.20	12.75	9.00	3.30	12.50	1.40	3.20	5.70	5.75
19	4.30	3.60	4.40	7.90	11.90	12.30	6.90	8.90	1.35	3.20	6.00	5.50
20	4.30	3.40	4.20	7.10	9.90	15.00	7.80	6.60	1.20	3.80	6.90	5.90
21	4.10	3.40	4.00	6.40	8.30	14.70	8.60	6.00	1.10	6.30	9.00	6.70
22	4.20	3.80	3.80	5.70	6.50	15.80	7.80	5.70	1.00	11.80	11.10	7.30
23	5.10	4.50	3.60	5.20	5.60	13.50	6.15	7.80	1.20	10.40	10.80	8.20
24	6.90	5.00	3.50	4.90	10.60	10.20	4.90	6.80	2.00	12.10	9.80	9.50
25	7.40	4.90	3.45	4.80	21.61	7.40	4.60	5.30	21.28	22.30	9.20	14.80
26	7.30	4.60	3.40	5.50	22.66	5.10	5.90	4.20	22.73	22.10	9.30	17.80
27	8.50	4.20	3.50	8.10	22.20	4.00	7.25	3.30	23.88	20.98	8.90	15.20
28	12.00	3.80	4.10	9.40	20.60	3.20	6.90	4.80	23.20	16.50	7.90	12.75
29	13.50	.....	4.80	8.50	18.30	2.90	5.30	4.70	20.60	14.30	7.00	10.80
30	12.00	.....	5.10	7.20	16.00	3.15	5.80	5.00	17.00	12.40	7.20	9.50
31	10.10	.....	6.00	.....	13.30	.....	8.10	4.80	.....	11.20	.....	8.00

Daily gage height, in feet, of Tar River at Tarboro, North Carolina, for 1

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	D
1	3.40	3.30	1.80	7.30	4.50	5.70	1.80	1.20	8.30	1.60	1.70	4
2	3.00	3.25	1.65	9.20	3.70	6.10	1.10	2.15	6.30	1.20	2.20	4
3	2.90	3.10	1.55	8.90	3.40	5.00	.90	2.80	4.10	.80	2.30	5
4	2.70	2.80	1.70	7.00	2.85	4.10	.60	4.00	3.20	1.20	1.80	6
5	2.40	2.60	3.20	5.90	2.50	3.00	.50	3.20	3.10	1.30	1.70	8
6	2.20	2.40	5.00	6.20	2.30	2.40	1.90	2.30	2.80	1.40	2.90	1
7	2.25	2.30	7.30	8.00	3.00	2.00	7.50	1.80	2.60	1.30	2.50	1
8	2.12	2.30	7.00	9.80	4.60	1.70	9.90	1.60	2.10	1.20	2.60	1
9	2.00	2.40	4.90	9.10	7.10	1.50	9.60	1.30	2.60	1.60	2.70	1
10	1.90	2.20	4.00	6.40	7.80	1.30	8.50	1.00	3.20	1.50	2.90	9
11	2.00	2.10	3.70	5.50	6.50	1.10	11.20	.90	2.60	1.60	2.30	7
12	2.05	2.00	3.50	5.10	4.90	1.00	11.70	1.50	1.70	1.50	2.80	5
13	2.30	1.90	3.20	4.50	4.10	.80	10.70	2.10	1.50	1.40	1.50	5
14	2.75	1.90	2.90	4.10	4.00	1.50	8.80	4.10	1.30	1.10	1.40	4
15	2.70	2.00	3.60	4.00	3.60	1.00	7.90	4.20	1.00	1.00	1.60	4
16	2.60	1.70	5.00	3.80	3.30	1.90	6.30	3.40	.80	.80	1.70	3
17	2.40	1.70	5.80	3.50	5.95	3.30	5.20	2.40	.70	.50	2.10	4
18	2.90	1.60	4.70	3.30	8.40	5.60	4.30	2.30	.60	.70	2.30	3
19	3.00	1.55	4.20	3.10	9.80	5.40	4.20	2.10	.50	.60	2.50	3
20	2.73	1.50	4.00	2.80	9.00	5.50	3.70	2.50	.50	2.60	4.30	3
21	2.60	1.60	3.60	2.60	7.20	6.70	4.20	5.30	.50	3.00	4.90	3
22	2.60	2.30	3.40	2.40	5.70	6.30	3.15	6.50	.40	2.80	5.50	4
23	2.70	2.40	3.00	2.20	4.60	5.30	2.80	6.00	.60	2.30	4.30	4
24	2.55	2.50	2.70	2.00	5.10	4.10	2.40	5.30	4.70	1.90	3.70	6
25	2.70	2.45	2.40	1.90	8.90	3.10	2.20	5.50	7.30	2.30	3.40	6
26	3.00	2.30	2.50	2.30	11.00	2.50	1.90	4.60	6.20	2.00	3.20	4
27	3.95	2.00	2.40	2.90	12.80	2.00	2.00	2.80	4.00	2.70	3.20	4
28	5.90	1.70	2.30	4.20	13.70	2.30	1.50	3.20	2.80	2.50	2.90	4
29	5.40	.....	2.30	5.30	12.40	2.50	1.40	4.50	2.20	2.80	3.00	4
30	4.20	.....	2.20	5.20	9.10	2.70	1.30	8.80	2.10	2.70	3.70	3
31	3.50	.....	2.50	.....	6.50	.....	1.30	8.90	.....	1.30	.....	3

Daily gage height, in feet, of Neuse River at Selma, North Carolina, for

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	D
1	1.70	1.30	1.00	11.40	1.50	2.70	0.50	0.70	6.00	0.30	3.00	3
2	1.70	1.30	1.00	10.20	1.20	2.00	.50	.80	5.80	.30	3.60	3
3	1.50	1.30	1.00	6.70	1.00	1.40	.60	1.10	1.80	.20	2.00	3
4	1.30	1.30	1.40	6.00	.80	1.00	.70	1.00	1.00	.30	1.60	3
5	1.20	1.30	1.50	7.20	.60	.90	.70	.60	4.50	.50	1.20	1
6	1.10	1.20	1.80	10.70	.80	.80	3.00	.50	3.20	.60	1.20	1
7	1.00	1.10	8.30	8.00	4.00	.70	5.90	.50	4.10	.70	1.20	1
8	.90	1.10	3.70	7.00	6.90	.60	6.00	.50	3.40	2.00	1.30	3
9	1.20	1.10	3.20	6.00	5.40	.50	5.80	.50	2.10	1.00	1.40	3
10	1.30	1.00	2.00	2.90	4.10	.50	5.30	.60	3.40	1.10	1.40	3
11	1.00	1.10	2.50	2.80	3.00	.50	5.00	.50	3.00	1.10	1.50	3
12	1.00	1.00	1.70	2.70	3.60	5.00	2.50	1.80	2.80	1.20	1.60	3
13	1.20	1.00	1.60	2.00	2.80	4.00	2.00	3.20	2.40	1.30	1.70	3
14	1.50	1.00	1.80	2.00	2.00	3.40	2.00	3.30	2.00	1.00	1.90	3
15	1.50	1.00	2.80	1.80	8.90	3.00	1.90	3.40	1.80	.80	2.00	1
16	1.20	1.00	5.10	1.80	8.00	2.00	1.80	3.00	1.00	.60	2.00	1
17	1.30	1.00	6.00	1.70	7.00	1.40	1.50	2.80	1.00	.40	2.60	1
18	1.60	1.00	5.00	1.50	5.40	1.50	2.00	2.80	1.00	.90	3.00	1
19	1.30	.80	4.20	1.40	3.60	1.80	4.00	1.30	1.00	1.40	5.40	1
20	1.30	1.00	3.70	1.30	2.70	2.00	7.00	9.60	1.10	1.80	5.80	1
21	1.20	1.00	2.00	1.20	2.00	2.20	5.00	10.40	1.20	1.90	5.00	3
22	1.60	1.80	1.70	1.10	3.00	2.00	2.70	6.30	1.30	2.30	4.50	3
23	1.40	2.50	1.40	1.20	5.00	1.80	2.00	2.60	4.00	1.90	3.00	3
24	1.30	1.80	1.20	1.30	9.00	1.00	1.00	2.50	12.00	1.50	2.80	3
25	1.40	1.40	2.00	1.50	10.00	.90	.90	2.80	13.00	1.60	2.20	3
26	3.50	1.30	2.50	1.70	11.00	.50	.80	1.60	9.40	1.80	2.00	3
27	7.00	1.20	1.80	2.00	7.00	.50	.80	1.80	6.10	1.60	1.90	3
28	5.80	1.00	2.00	3.70	5.50	.50	.70	8.90	1.00	1.20	1.80	1
29	3.40	.....	3.00	5.00	4.00	.50	.70	5.40	1.00	1.00	2.00	1
30	2.30	.....	7.00	4.20	3.50	.40	.70	9.10	.80	1.40	2.50	1
31	1.90	.....	9.00	.....	3.00	.....	.70	9.00	.....	2.60	.....	1

Daily gage height, in feet, of Haw River at Moncure, North Carolina, for 1898.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	2.16	1.88	1.88	4.12	1.60	5.34	3.24
2	.....	2.10	1.65	1.96	3.18	1.48	4.28	2.88
3	.....	1.92	1.60	1.86	2.38	1.66	3.44	2.52
4	.....	1.85	1.40	1.80	7.40	1.38	2.62	6.62
5	.....	1.50	1.20	1.60	11.88	2.00	2.55	7.44
6	1.30	1.60	1.80	1.60	7.78	2.86	2.12	6.48
7	5.00	1.50	7.38	1.62	5.22	2.94	2.10	5.20
8	4.50	1.52	3.12	1.50	5.46	2.86	3.00	4.26
9	3.65	1.60	2.30	1.22	4.45	1.72	2.76	3.28
10	3.00	1.50	1.90	1.20	3.74	1.48	2.25	3.16
11	2.50	1.44	2.00	1.30	2.32	1.54	2.42	2.94
12	2.23	1.40	1.38	1.76	2.10	1.60	2.12	2.25
13	1.87	1.40	1.40	2.70	2.04	1.52	2.38	2.54
14	3.10	1.30	1.70	5.98	1.64	1.50	2.67	2.40
15	2.60	2.10	1.85	5.30	1.65	1.51	3.24	2.36
16	2.00	3.10	1.60	3.00	1.60	1.34	3.00	2.22
17	2.30	1.70	1.60	2.94	1.62	1.23	5.23	2.20
18	2.20	1.70	5.60	3.86	1.65	1.66	6.44	2.34
19	2.22	2.30	3.40	10.30	1.62	2.65	6.08	2.12
20	2.00	2.96	4.10	15.85	1.64	1.27	5.62	2.78
21	1.80	3.34	2.44	14.92	1.46	1.94	4.28	2.41
22	1.74	2.60	1.92	10.64	1.44	7.64	3.84	2.22
23	1.60	2.10	4.98	7.25	11.35	5.56	3.02	3.46
24	8.20	1.22	2.80	5.18	9.14	3.28	2.84	3.21
25	6.14	1.30	2.34	3.32	5.28	2.42	2.06	3.34
26	4.46	1.64	2.12	2.14	4.00	2.50	2.00	2.78
27	4.00	1.52	1.90	2.18	2.64	2.14	2.48	2.37
28	3.10	1.58	2.38	2.25	2.92	2.22	2.92	2.30
29	2.42	1.85	2.10	2.38	1.88	1.88	2.58	2.48
30	2.00	1.90	2.16	7.14	1.52	7.16	2.92	2.36
31	2.00	.....	1.98	4.97	.....	9.98	.....	2.34

Daily gage height, in feet, of Deep River at Moncure, North Carolina, for 1898.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	1.75	1.76	1.12	3.82	1.52	5.72	2.95
2	.....	1.50	1.53	2.00	3.50	1.92	4.89	3.27
3	.....	1.62	1.34	1.80	2.64	1.88	3.22	3.20
4	.....	1.50	1.20	2.00	4.84	1.54	2.78	7.90
5	1.96	1.42	1.14	1.98	12.62	2.92	2.44	9.49
6	1.90	1.20	2.80	1.52	8.67	2.84	2.14	6.34
7	2.30	1.25	7.80	1.50	7.14	2.74	3.92	5.42
8	3.50	1.20	4.52	1.24	5.72	2.22	3.64	4.60
9	3.70	1.24	2.90	1.22	5.88	1.68	2.98	3.14
10	2.74	1.20	2.16	1.20	4.22	1.56	2.76	3.00
11	2.40	1.14	3.60	1.46	3.40	1.54	2.51	2.34
12	2.00	1.54	2.40	1.50	2.48	1.51	2.16	2.32
13	1.74	1.20	1.72	2.66	2.08	1.50	3.28	2.30
14	2.65	1.22	1.84	8.12	1.85	1.54	2.76	2.28
15	2.20	1.30	1.72	12.10	1.08	1.52	2.52	2.25
16	2.10	1.35	1.78	3.82	1.98	1.36	3.51	2.26
17	1.94	2.10	1.75	2.68	1.67	1.32	2.13	2.12
18	2.00	1.94	4.00	4.88	1.52	1.92	5.54	2.25
19	2.10	1.82	2.74	9.00	1.50	3.56	6.28	2.30
20	1.98	2.24	2.86	19.10	1.56	3.22	4.94	2.10
21	1.76	2.65	2.12	18.84	1.48	2.42	4.08	2.54
22	1.64	2.98	1.16	14.13	1.19	8.98	3.76	2.32
23	1.50	2.38	4.22	9.62	2.22	6.00	2.96	4.18
24	6.20	1.94	3.14	5.37	10.44	3.56	2.48	3.70
25	6.54	1.72	2.32	3.12	4.56	3.44	2.21	3.28
26	4.96	1.35	1.94	3.00	3.65	2.98	2.05	3.22
27	3.48	1.36	1.98	2.57	2.68	2.21	2.34	2.48
28	2.28	1.22	1.90	3.30	2.14	2.01	2.24	2.76
29	2.20	1.24	1.82	3.52	1.96	1.99	2.31	2.72
30	1.98	1.78	1.88	6.73	1.80	6.70	3.10	2.40
31	1.70	.....	1.82	5.58	.....	8.76	.....	2.26

Daily gage height, in feet, of Cape Fear River at Fayetteville, North Carolin
1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	I
1	5.00	5.00	3.50	21.00	6.60	3.20	2.00	6.00	10.30	2.90	14.00	
2	4.90	4.90	3.20	17.30	5.50	3.00	2.00	7.00	9.60	2.50	9.30	
3	4.50	4.80	3.50	11.00	5.00	3.00	1.50	7.00	7.20	2.40	7.10	
4	4.30	4.40	3.50	9.40	4.30	2.70	1.20	6.40	5.70	2.50	5.50	
5	3.70	4.00	7.00	6.00	4.10	2.30	1.00	5.20	14.00	2.40	4.70	1
6	3.70	3.90	20.50	12.80	3.80	1.90	5.10	5.00	18.80	2.50	4.20	1
7	3.60	3.80	17.70	21.50	3.10	1.40	12.00	4.10	14.00	5.50	3.80	1
8	4.00	3.60	11.00	15.30	8.00	1.20	16.20	3.00	12.50	5.60	5.40	1
9	3.60	3.50	8.70	11.70	7.00	1.10	12.40	3.00	13.20	4.20	5.00	
10	3.50	3.40	7.90	8.00	6.30	1.20	10.20	2.60	10.00	3.40	4.80	
11	3.40	3.40	5.80	7.00	5.40	1.10	12.50	2.30	8.70	2.70	4.30	
12	3.30	3.50	5.20	6.10	4.50	1.10	8.00	3.70	6.50	2.30	3.70	
13	3.40	3.50	4.90	5.90	4.00	1.20	6.00	5.00	5.00	2.00	3.50	
14	3.60	3.40	5.00	5.70	3.70	1.30	5.10	9.40	4.30	1.90	3.90	
15	3.80	3.20	5.10	5.40	5.00	1.30	5.10	16.00	4.10	1.80	4.30	
16	3.60	2.90	8.00	5.40	4.90	2.50	5.50	14.00	3.80	1.80	6.00	
17	3.70	2.90	9.20	5.60	5.10	3.90	5.50	10.00	3.60	1.50	7.00	
18	3.60	2.90	7.70	5.40	4.70	4.30	4.10	7.00	3.40	1.30	9.80	
19	3.70	3.10	6.20	4.70	4.20	3.90	6.00	9.20	3.10	2.00	10.20	
20	3.80	4.50	5.50	4.40	4.00	4.00	5.50	22.20	2.90	5.00	11.00	
21	3.60	5.30	5.00	4.20	3.50	7.00	5.50	29.00	2.50	5.00	12.20	
22	4.10	5.70	5.00	4.00	3.00	7.00	4.20	29.20	2.20	4.50	9.60	
23	4.40	6.00	4.70	3.90	3.00	5.50	3.60	23.50	2.50	10.00	7.80	
24	4.40	5.50	4.50	4.10	2.90	4.30	10.00	18.00	15.00	9.80	5.60	
25	4.40	5.10	4.20	4.40	12.00	3.20	7.00	10.30	14.00	6.00	5.10	
26	5.50	4.50	5.00	7.20	11.40	2.70	6.00	6.00	9.80	4.50	5.00	
27	14.00	4.10	6.00	10.40	9.00	2.20	4.60	6.10	7.00	4.70	5.10	
28	11.00	3.80	5.60	10.70	6.70	1.70	4.10	6.20	5.00	4.50	4.70	
29	9.20	.....	4.70	12.00	5.00	1.60	4.00	7.00	3.90	3.60	4.40	
30	6.50	.....	4.30	9.60	4.00	2.10	3.90	8.50	3.40	3.50	4.70	
31	5.30	.....	14.80	.....	3.50	.....	4.00	11.00	.....	10.00	.....	

Daily gage height, in feet, of Yadkin River at Salisbury, North Carolina, fo

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	I
1	2.00	2.00	1.70	4.70	1.80	1.80	1.70	1.80	2.30	1.80	2.40	
2	2.00	2.00	1.70	3.00	1.80	1.80	1.70	1.70	2.00	1.80	2.40	
3	2.00	2.00	1.80	2.80	1.80	1.70	1.50	2.00	1.80	1.90	2.00	
4	2.00	1.90	2.20	2.30	1.80	1.70	1.30	3.00	2.00	2.20	1.80	
5	2.00	1.90	2.10	2.70	2.60	1.80	1.30	3.10	4.50	3.65	1.80	
6	1.90	1.90	2.00	2.70	2.00	1.70	1.80	3.00	4.00	7.10	1.80	
7	1.90	1.90	1.90	2.40	3.00	1.60	1.90	2.20	3.80	5.00	1.80	
8	1.90	1.80	1.90	2.00	2.60	1.60	2.30	2.00	3.00	3.20	1.70	
9	1.90	1.80	1.90	2.00	2.00	1.60	1.70	1.90	2.10	2.20	1.80	
10	1.90	1.70	1.90	2.00	1.70	1.50	1.70	2.00	1.80	1.90	1.90	
11	1.90	1.70	1.80	2.00	1.70	1.50	1.60	3.00	1.60	1.80	1.80	
12	1.90	1.60	1.80	1.90	1.80	2.00	2.70	4.50	1.60	1.80	1.70	
13	1.90	1.60	2.00	1.90	2.00	2.10	1.80	5.30	1.60	1.90	1.70	
14	1.90	1.60	2.60	1.90	2.80	1.70	1.80	4.30	1.50	1.90	1.80	
15	2.00	1.50	2.90	1.80	1.80	1.80	1.50	3.80	1.50	1.80	1.80	
16	2.00	1.50	2.80	1.80	1.70	1.80	2.40	2.80	1.50	1.80	2.00	
17	2.20	1.50	2.60	1.60	1.60	1.70	2.00	2.20	1.50	1.70	2.80	
18	2.00	1.80	2.30	1.60	1.80	2.10	1.80	2.00	1.60	1.70	1.70	
19	2.00	2.00	2.80	1.70	1.70	2.00	1.80	1.80	1.60	1.70	1.80	
20	3.00	2.10	2.00	1.70	1.70	2.00	2.00	3.50	1.50	2.30	1.70	
21	2.60	2.20	1.90	1.70	1.80	1.90	1.80	5.70	1.50	2.50	1.80	
22	2.60	2.00	1.90	1.90	1.80	1.80	2.10	4.10	1.50	5.05	2.00	
23	2.60	2.10	1.80	2.00	2.95	1.80	2.90	2.70	5.65	5.70	2.30	
24	3.00	1.80	1.80	2.30	5.35	1.70	2.80	2.60	13.40	3.80	2.00	
25	3.90	1.80	1.80	3.10	3.00	1.70	3.00	1.70	14.80	3.80	2.10	
26	4.00	1.80	1.80	2.20	2.80	1.70	2.80	1.90	6.20	2.60	1.90	
27	3.20	1.60	1.90	2.20	2.00	1.60	3.00	2.20	2.20	2.00	1.90	
28	2.80	1.60	2.00	1.90	2.00	1.60	3.00	2.00	1.80	1.90	1.80	
29	2.60	.....	2.10	1.80	1.90	1.80	4.60	1.80	1.80	1.90	1.80	
30	2.60	.....	3.60	1.80	1.70	1.80	3.90	4.95	1.90	1.80	1.80	
31	2.40	.....	6.10	.....	1.70	.....	2.00	4.00	.....	2.00	.....	

aily gage height, in feet, of Yadkin (Pedee) River at Norwood, North Carolina, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.80	1.80	1.50	4.20	1.80	1.70	1.20	1.90	2.40	1.90	1.90	2.10
2	1.80	1.90	1.60	3.40	1.70	1.60	1.20	1.70	2.60	1.70	1.70	2.20
3	1.80	1.70	1.70	2.50	1.60	1.50	1.00	1.80	2.50	1.60	2.10	2.20
4	1.70	1.50	2.30	2.40	1.60	1.30	1.00	1.70	1.90	1.80	2.20	3.10
5	1.50	1.60	2.50	3.00	1.50	1.30	.90	1.60	2.20	1.90	2.30	4.70
6	1.60	1.70	2.40	4.50	1.50	1.30	1.30	1.50	4.10	5.60	2.90	4.50
7	1.70	1.60	2.10	3.40	1.60	1.20	2.00	2.00	3.60	4.60	2.70	3.60
8	1.70	1.60	1.90	2.60	2.30	1.20	1.70	1.70	2.70	2.90	2.50	3.40
9	1.60	1.50	1.80	2.30	2.00	1.30	1.40	1.60	2.60	2.40	2.10	3.90
10	1.50	1.50	1.80	2.20	1.80	1.20	1.40	1.50	2.40	2.30	1.90	2.90
11	1.70	1.60	1.60	2.10	1.60	1.30	1.50	1.60	1.90	2.10	1.80	2.20
12	1.70	1.60	1.60	2.00	1.60	1.30	2.10	1.90	1.70	1.90	1.70	2.10
13	1.60	1.60	1.50	1.80	1.70	1.60	1.70	3.00	1.20	1.80	1.80	1.90
14	1.70	1.70	1.70	1.90	1.80	1.30	1.80	1.50	1.50	1.70	2.10	1.90
15	1.70	1.90	2.50	2.00	1.70	1.40	2.10	3.60	1.50	1.80	2.30	1.80
16	1.60	1.70	2.60	2.20	1.60	1.30	1.10	2.50	1.40	1.90	3.20	1.70
17	1.60	1.70	2.70	2.00	1.50	1.40	2.10	2.00	1.20	1.70	2.70	1.80
18	1.60	1.60	2.00	1.90	1.40	2.30	1.90	2.60	1.50	1.80	2.90	1.90
19	1.50	1.70	1.90	1.80	1.40	1.80	1.30	1.90	1.40	1.90	3.10	2.10
20	1.50	1.80	2.30	1.80	1.50	2.20	1.40	1.70	1.30	2.70	3.20	2.20
21	1.70	1.90	2.20	1.70	1.40	2.10	1.30	4.00	1.30	2.60	2.90	2.30
22	2.60	1.90	1.90	1.70	1.40	1.80	1.20	3.20	1.20	2.90	2.40	2.50
23	2.20	1.80	1.70	1.80	2.80	1.60	1.70	2.20	1.50	5.40	2.30	2.90
24	2.00	1.70	1.80	1.90	4.80	1.50	2.20	2.10	7.00	3.80	2.40	3.90
25	2.30	1.60	1.90	2.30	3.80	1.40	2.90	1.90	11.00	2.70	2.20	3.70
26	3.60	1.60	2.10	3.40	2.60	1.20	2.20	1.30	7.00	2.50	2.30	3.90
27	3.70	1.60	2.00	2.30	2.30	1.10	2.90	1.70	3.70	2.40	2.10	3.70
28	3.00	1.50	1.70	2.10	2.00	1.40	2.00	2.50	2.40	2.30	1.90	2.30
29	2.40	.....	1.80	1.80	1.80	1.40	2.30	3.00	2.20	2.20	1.80	2.10
30	2.10	.....	5.70	1.80	1.60	1.30	3.00	3.40	2.00	2.70	1.90	1.90
31	2.00	.....	6.10	.....	1.80	.....	2.30	2.70	.....	2.50	.....	1.80

aily gage height, in feet, of Catawba River at Catawba, North Carolina, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.00	2.20	1.95	3.30	2.10	1.90	1.80	3.45	2.90	3.70	3.10	2.60
2	2.00	2.10	1.95	3.00	2.10	1.90	1.80	3.40	2.60	3.00	2.95	2.60
3	2.00	2.05	1.90	2.60	2.10	1.80	1.80	3.00	3.30	3.50	2.80	2.60
4	1.95	2.00	1.90	2.40	2.05	1.80	1.80	2.75	5.50	9.70	2.80	4.50
5	1.90	2.00	1.90	3.00	2.25	1.80	2.00	9.65	5.65	11.50	2.28	5.60
6	1.90	2.00	1.90	2.90	2.60	1.80	2.50	4.30	4.35	7.20	2.75	3.90
7	2.00	2.00	1.90	2.60	2.50	1.80	2.35	4.00	4.90	6.10	2.70	3.40
8	2.05	2.00	1.90	2.30	2.35	1.80	2.50	3.50	3.90	5.00	2.65	3.00
9	2.00	2.00	1.90	2.20	2.25	1.75	2.80	3.55	3.60	4.10	2.60	2.90
10	1.95	2.00	1.90	2.15	2.15	1.75	2.35	3.70	3.15	3.80	2.60	2.85
11	1.95	2.00	1.90	2.15	2.05	1.75	2.00	4.60	2.60	3.60	2.60	2.80
12	2.00	2.00	1.90	2.10	2.00	1.75	2.00	6.50	2.40	3.40	2.60	2.70
13	2.00	2.00	1.90	2.10	2.00	1.70	1.85	4.80	2.35	3.20	2.60	2.70
14	2.00	2.00	1.90	2.10	1.95	1.70	4.20	3.50	2.30	3.10	2.70	2.65
15	2.00	2.00	1.90	2.10	1.90	1.90	7.00	3.20	2.30	2.95	2.75	2.50
16	1.95	1.95	1.90	2.40	1.90	2.00	4.10	3.10	2.20	2.80	2.75	2.50
17	1.95	1.95	2.00	2.30	1.90	3.50	4.00	2.90	2.10	2.80	2.80	2.50
18	1.95	1.95	2.10	2.25	1.90	2.80	3.70	2.90	2.10	3.40	3.00	2.50
19	1.95	1.95	2.05	2.20	1.85	2.00	3.10	4.30	2.10	3.20	3.30	2.50
20	2.25	1.95	2.05	2.20	1.85	1.95	2.50	4.30	2.10	3.50	3.20	2.50
21	3.00	2.00	2.00	2.20	1.85	1.95	2.40	4.00	2.05	8.30	3.00	2.90
22	3.00	2.00	2.00	2.20	1.85	1.80	2.40	3.20	2.40	7.45	2.80	3.00
23	2.75	2.00	2.00	2.30	1.85	1.80	3.00	3.00	19.95	6.60	2.95	3.15
24	2.50	1.95	2.00	2.25	3.50	1.80	4.50	2.50	11.60	5.00	3.10	3.25
25	3.00	1.95	1.95	2.20	2.50	1.80	3.90	2.50	5.70	4.10	3.00	3.10
26	5.50	1.95	1.95	2.15	2.20	1.80	3.30	2.60	5.40	3.80	2.85	3.00
27	3.40	1.95	2.90	2.10	2.00	1.80	2.80	2.55	4.90	3.50	2.70	3.00
28	3.00	1.95	3.00	2.10	1.90	1.85	3.40	2.45	4.10	3.30	2.70	2.90
29	2.75	.....	3.50	2.10	1.95	1.80	3.50	5.60	3.40	3.30	2.70	2.85
30	2.40	.....	7.50	2.10	1.95	1.80	3.10	3.30	3.30	3.30	2.65	2.85
31	2.30	.....	5.50	.....	1.95	.....	3.50	3.10	.....	3.20	.....	2.90

Daily gage height, in feet, of Tugalo River at Madison, South Carolina, fo

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	July.	Aug.	Sept.	Oct.	Nov.
1	.....	2.30	6.40	3.00	3.60	5.00	17	.....	4.10	3.70	4.30	3.60
2	.....	2.10	20.00	2.80	3.50	3.40	18	.....	6.40	3.60	9.35	3.60
3	.....	6.20	17.00	3.10	3.40	3.40	19	2.10	5.70	3.40	6.20	4.70
4	.....	9.75	13.00	18.00	3.30	3.50	20	1.90	5.70	3.30	5.00	4.00
5	.....	9.20	8.20	22.00	3.40	4.30	21	1.80	4.30	3.20	5.50	3.60
6	.....	6.70	7.30	14.00	4.10	3.60	22	1.70	3.80	3.40	6.30	3.40
7	.....	5.40	6.30	8.70	3.40	3.50	23	4.10	3.40	8.10	5.20	6.30
8	.....	6.10	5.40	7.80	3.30	3.40	24	4.40	3.40	4.30	4.70	4.70
9	.....	4.70	4.90	6.80	3.20	3.30	25	4.50	3.80	3.70	4.50	4.10
10	.....	4.80	4.90	6.20	3.30	3.20	26	4.00	3.90	3.40	4.30	3.90
11	.....	8.90	4.80	5.80	4.10	3.60	27	2.90	3.60	3.30	4.20	3.60
12	.....	7.95	4.50	5.50	3.40	3.00	28	4.10	3.10	3.20	4.10	3.40
13	.....	6.70	4.20	5.10	3.30	2.90	29	3.00	2.90	3.20	3.90	3.50
14	.....	7.90	4.10	4.80	4.00	2.90	30	2.80	3.40	3.10	3.90	3.80
15	.....	4.80	3.90	4.60	3.50	2.80	31	2.30	3.20	.....	3.70	.....
16	.....	4.50	3.80	4.40	3.40	2.80						

Daily gage height, in feet, of Savannah River at Calhoun Falls, South Ca for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	A
1	2.30	3.25	2.30	4.60	2.65	1.80	1.75	
2	2.30	3.10	2.35	3.40	2.75	1.80	1.70	
3	2.25	3.00	2.45	3.25	2.80	1.80	1.65	
4	2.25	2.90	2.80	3.00	2.80	1.75	1.60	
5	2.20	2.85	3.00	4.45	2.75	1.95	1.90	
6	2.40	2.80	2.80	4.00	2.70	2.05	2.45	
7	2.35	2.75	2.65	3.80	2.60	2.00	2.75	
8	2.30	2.65	2.60	3.55	2.55	1.95	3.95	
9	2.25	2.60	2.50	3.20	2.50	1.85	3.05	a
10	2.25	2.60	2.45	3.00	2.50	1.80	2.60	...
11	2.20	2.55	2.35	3.15	2.40	1.75	2.45	...
12	2.20	2.60	2.25	3.05	2.25	1.75	2.30	...
13	2.15	2.50	2.20	3.00	2.15	1.95	2.50	...
14	2.15	2.50	2.25	3.00	2.00	1.90	4.90	...
15	2.20	2.45	2.50	2.90	2.20	1.90	5.05	...
16	2.40	2.40	2.40	2.70	2.10	1.95	3.95	...
17	2.35	2.35	2.45	2.65	2.05	2.00	3.60	...
18	2.35	2.30	2.35	2.55	2.00	2.05	3.40	...
19	2.45	2.30	2.30	2.50	2.05	2.25	3.25	...
20	2.85	2.30	2.30	2.65	2.00	2.35	3.00	...
21	2.70	2.35	2.30	2.50	1.90	2.05	2.85	...
22	2.65	2.30	2.25	2.45	2.00	2.00	2.50	...
23	2.90	2.30	2.20	2.35	1.95	1.95	2.75	...
24	2.85	2.25	2.25	2.75	1.95	1.90	4.00	...
25	3.65	2.25	2.25	3.00	1.90	1.85	4.50	...
26	5.50	2.25	2.20	2.85	1.85	1.90	4.05	...
27	4.65	2.35	2.20	3.05	1.85	1.85	3.85	...
28	4.05	2.40	2.25	2.90	1.80	1.80	4.00	...
29	3.85	.....	2.30	2.80	1.80	1.80	3.75	...
30	3.60	.....	3.90	2.70	1.85	1.80	3.90	...
31	3.45	.....	6.75	.....	1.80	.....	3.65	...

a Discontinued.

Daily gage height, in feet, of Savannah River at Augusta, Georgia, for 1896.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	12.0	8.3	10.3	7.8	8.4	5.1	4.7	5.9	4.5	8.7	5.0	14.5
2	10.3	8.2	9.1	7.9	7.3	5.5	4.3	6.2	4.3	6.2	5.8	16.0
3	8.7	9.8	8.3	9.6	7.7	7.7	4.4	7.0	4.2	5.3	5.5	16.8
4	7.9	13.3	7.8	8.8	8.2	8.8	4.3	6.6	4.2	5.0	5.2	14.5
5	7.3	12.0	7.7	7.5	10.6	8.2	9.8	6.4	4.0	4.7	15.2	13.0
6	7.0	19.1	7.5	7.0	9.7	7.5	6.3	6.3	4.9	4.5	20.9	11.2
7	6.7	22.7	7.6	7.1	9.9	6.5	8.8	5.7	11.2	4.3	17.3	10.1
8	6.7	20.5	8.0	6.9	8.2	5.8	22.4	5.2	8.7	4.1	11.0	10.2
9	7.2	24.2	8.0	6.8	7.2	5.7	29.2	4.9	6.1	3.9	8.1	9.8
10	8.0	24.3	7.8	6.7	6.7	5.7	30.2	4.8	5.2	3.8	7.0	9.2
11	7.6	19.5	7.5	6.6	6.3	5.7	25.8	4.8	4.8	4.0	6.6	8.9
12	6.9	14.8	9.6	7.2	6.0	6.4	20.1	5.2	4.7	3.8	6.0	8.4
13	6.7	12.7	10.5	6.5	5.9	6.0	15.0	5.3	4.9	3.8	9.6	7.9
14	6.5	11.2	9.9	6.6	5.8	5.5	11.7	4.9	4.4	3.9	13.4	7.3
15	6.4	12.0	8.0	6.5	5.7	5.0	9.5	6.0	4.2	4.0	10.6	8.3
16	6.5	11.6	7.7	6.5	5.7	4.9	8.6	6.0	4.2	4.7	8.3	17.6
17	10.3	10.4	7.7	6.3	5.6	4.7	8.0	5.8	4.0	4.1	7.2	15.4
18	16.7	9.6	7.8	6.2	5.5	4.6	8.0	5.5	4.2	4.2	6.8	11.8
19	14.5	9.1	7.6	6.3	5.4	4.8	8.0	5.0	4.0	3.9	6.2	9.9
20	11.0	8.8	8.0	6.2	5.2	6.2	8.8	4.9	4.8	3.9	6.0	8.3
21	8.9	8.6	8.2	5.9	5.1	6.1	8.8	4.8	3.9	3.8	6.0	8.0
22	8.3	8.2	8.4	5.8	5.0	5.9	8.8	4.6	3.8	3.7	5.9	7.2
23	9.0	7.9	8.0	5.8	4.9	6.0	8.4	4.5	3.8	3.4	5.7	7.3
24	17.8	8.0	7.7	5.7	5.8	5.9	8.6	4.4	3.9	3.5	5.6	6.9
25	22.2	8.0	7.8	8.8	6.3	5.8	7.8	3.9	5.2	4.8	5.4	6.9
26	18.5	8.0	8.0	7.7	6.6	5.3	7.2	5.2	4.9	5.9	5.3	6.6
27	14.1	7.9	7.7	7.2	5.9	5.0	6.2	4.9	4.8	5.5	5.5	6.1
28	11.3	7.8	7.6	6.9	5.8	4.9	6.0	5.8	4.0	5.0	5.3	6.5
29	9.9	9.2	7.2	6.8	5.7	4.9	6.8	5.7	3.9	4.8	6.3	6.0
30	9.0	.....	7.1	6.8	5.7	4.8	7.0	5.8	10.1	4.4	9.4	5.9
31	8.7	.....	7.1	.....	5.6	.....	6.6	4.9	.....	4.0	.....	5.8

Daily gage height, in feet, of Savannah River at Augusta, Georgia, for 1897.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	6.0	7.2	11.1	11.0	8.9	6.8	8.9	5.8	5.0	4.7	5.0	7.9
2	6.1	10.3	10.0	19.2	16.9	6.8	6.7	5.8	6.1	4.8	4.9	7.4
3	6.0	15.5	9.5	18.0	15.5	6.5	5.9	5.6	6.3	4.8	6.9	6.8
4	6.2	14.2	9.3	17.7	11.2	8.3	6.0	5.4	6.8	4.7	8.0	6.4
5	6.5	11.6	9.5	19.4	9.8	7.5	5.8	5.6	6.8	4.3	6.8	6.9
6	6.4	23.3	9.2	28.5	9.1	8.5	8.2	5.5	5.4	4.2	6.0	7.3
7	6.8	27.1	14.6	27.0	8.8	8.7	9.7	10.4	4.9	4.2	6.2	7.0
8	6.5	25.2	20.1	19.5	8.7	8.4	8.2	10.5	4.8	4.3	4.9	7.3
9	6.2	18.3	15.6	15.5	8.4	9.5	7.3	8.6	4.8	4.1	5.4	6.9
10	6.0	14.4	12.5	15.6	8.2	11.7	7.1	6.8	4.8	4.0	5.0	6.6
11	6.2	12.1	11.1	14.7	8.2	9.3	7.8	6.1	4.8	3.9	5.0	6.4
12	5.9	20.3	11.2	12.8	8.2	8.0	7.3	5.9	4.8	6.6	5.2	6.0
13	5.8	22.8	18.6	11.8	8.3	7.1	8.0	5.8	4.9	7.8	5.0	5.9
14	6.8	19.9	23.9	11.2	9.8	6.9	8.8	5.5	4.6	8.5	5.0	6.0
15	12.4	15.6	25.2	10.8	9.7	6.8	7.0	5.7	4.3	6.9	5.0	6.0
16	11.7	13.0	23.8	10.7	9.0	7.5	6.0	5.3	4.2	6.0	4.9	6.6
17	10.1	14.1	19.3	10.8	8.2	8.5	5.7	10.7	4.4	5.6	4.9	7.5
18	9.2	12.9	17.0	10.2	8.0	8.6	8.2	9.5	4.2	5.3	4.9	6.6
19	13.4	11.1	14.4	10.0	7.8	7.1	9.5	10.8	4.3	5.2	4.9	6.5
20	11.8	10.2	13.8	9.5	7.7	6.9	16.6	16.6	4.8	5.9	4.9	6.2
21	10.2	11.0	16.7	9.4	7.7	6.9	15.5	12.0	4.7	7.7	4.9	6.3
22	20.8	12.5	15.3	9.2	7.4	7.0	14.2	20.3	4.5	8.4	4.9	6.8
23	17.9	11.8	13.6	9.0	7.6	6.5	11.3	16.8	12.2	6.9	4.9	7.0
24	13.4	13.3	14.5	9.1	7.3	6.1	8.8	12.2	12.5	6.1	4.8	7.6
25	10.7	15.0	13.7	9.1	7.2	6.0	7.5	10.6	8.9	5.8	4.9	7.4
26	9.2	20.3	12.1	8.8	7.0	6.1	6.8	8.8	6.6	5.6	5.0	7.0
27	8.8	18.0	10.9	8.8	7.0	6.6	7.0	6.7	5.3	5.3	5.0	7.5
28	8.3	13.6	10.5	8.8	6.8	6.2	10.7	5.9	5.1	5.2	8.6	8.6
29	8.0	.....	9.8	8.5	6.8	5.9	8.7	5.7	5.0	5.0	9.4	8.2
30	7.6	.....	9.3	8.5	6.9	9.3	7.4	5.5	4.9	5.0	8.8	7.7
31	7.0	.....	9.4	.....	6.8	.....	6.0	5.3	.....	5.0	.....	6.9

Daily gage height, in feet, for Savannah River at Augusta, Georgia, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	6.5	7.8	6.0	15.9	8.3	4.5	4.0	8.0	15.3	7.2	8.4	10.0
2	6.3	7.5	5.9	12.5	7.6	4.7	3.8	7.8	28.4	7.1	8.0	9.2
3	6.2	7.1	5.9	9.7	7.3	4.7	4.0	6.9	28.4	7.2	7.9	9.6
4	6.0	6.8	6.2	8.5	7.0	4.5	4.2	6.5	27.8	17.9	7.8	12.7
5	5.9	6.7	10 0	9.0	6.8	4.4	3.7	8.4	27.0	17.8	7.6	16.2
6	6.0	6.5	9.1	17.7	6.5	4.2	3.3	15.5	22.6	24.0	7.5	14.8
7	6.2	6.4	7.6	18.0	6.5	4.6	8.4	12.4	18.2	23.4	8.3	12.4
8	6.3	6.5	6.8	14.0	6.8	4.5	10.6	10.7	15.9	16.7	8.7	10.5
9	5.9	6.3	6.5	10.9	6.0	4.4	12.4	10.4	17.9	13.5	7.8	9.6
10	6.1	6.3	6.0	9.0	6.1	4.4	9.9	9.2	13.7	11.4	7.5	9.0
11	6.0	6.1	6.0	8.5	5.9	4.0	12.3	8.3	11.5	10.7	7.4	8.8
12	6.0	6.2	6.0	8.9	5.9	4.8	8.5	10.0	9.9	9.8	7.8	8.8
13	6.2	6.1	6.0	8.4	5.9	4.4	9.6	11.1	9.0	9.3	8.2	8 5
14	6.3	6.0	6.0	8.0	5.9	4.2	14.0	14.4	8.7	9.0	10.1	8.4
15	6.3	6.0	8.7	8.5	6.7	4.2	16.4	11.8	8.5	8.6	11.0	8.1
16	6.1	5.9	11.8	8.2	6.0	4.4	17.5	13.5	8.2	8.8	10.3	8.0
17	6.1	5.9	9.0	7.9	5.6	4.5	13.9	10.8	8.0	7.8	17.4	7.9
18	6.0	5.9	8.0	7.2	5.5	5.3	9.4	9.6	7.9	7.6	15.5	8.0
19	6.0	6.2	7.6	7.0	5.7	6.1	7.8	11.8	7.1	8.4	14.3	7.9
20	6.0	6.2	7.5	6.9	5.6	8.0	6.9	19.9	7.6	12.0	15.0	8.0
21	6.0	6.5	6.9	7.0	5.8	9.7	6.4	15.0	7.4	9.6	13.1	8.5
22	8.2	6.5	6.5	7.2	5.6	8.4	5.9	11.8	7.3	15.5	10.8	10.8
23	8.8	6.0	6.5	6.8	5.4	7.0	5.7	9.9	7.9	17.2	9.5	10.2
24	7.2	5.9	6.4	9.2	5.2	5.7	9.8	8.7	13.0	13.8	9.4	13.5
25	7.5	5.9	6.0	11.8	5.3	5.0	17.7	7.9	11.8	11.0	10.3	13.3
26	12.4	5.9	5.9	11.2	5.9	5.3	15.5	8.4	9.4	9.6	9.3	11.2
27	16.7	5.8	5.9	9.1	5.7	4.5	13.2	10.5	8.3	9.0	9.0	10.0
28	14.2	5.9	5.8	10.9	5.6	4.3	10.4	14.8	7.9	8.6	8.8	9.3
29	11.0	.....	6.0	11.1	5.5	4.2	10.9	12.6	7.4	8.5	8.5	9.0
30	9.0	.....	5.4	9.8	4.6	4.0	11.3	15.9	7.3	8.2	9.4	8.6
31	8.2	.....	13.5	.....	4.8	.....	9.0	15.7	.....	8.3	.....	8.5

Daily gage height, in feet, of Broad River at Carlton, Georgia, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.05	2.25	1.90	3.60	2.20	1.60	1.40	2.10	9.10	2.15	2.35	2.75
2	2.00	2.15	1.90	2.75	2.15	1.60	1.35	1.95	18.85	2.10	2.35	2.55
3	1.95	2.10	1.95	2.45	2.05	1.60	1.35	1.80	18.53	3.20	2.30	2.80
4	1.95	2.05	2.10	2.30	2.05	1.60	1.40	3.00	13.38	4.85	2.30	3.90
5	1.95	2.00	2.15	5.25	2.00	1.55	1.80	3.85	7.88	11.20	2.30	3.50
6	1.95	2.05	2.05	4.45	2.00	1.50	2.85	4.00	5.00	10.10	3.20	3.10
7	1.95	2.05	2.00	3.00	2.00	1.45	3.50	4.20	4.60	4.35	2.40	2.85
8	1.95	2.00	1.95	2.60	1.95	1.45	2.60	3.40	4.50	3.25	2.35	2.70
9	1.95	2.00	1.90	2.45	1.95	1.40	2.30	2.50	3.50	2.90	2.35	2.60
10	1.90	2.00	1.90	2.40	1.90	1.35	1.95	2.20	2.90	2.70	2.65	2.55
11	1.90	2.00	1.85	2.45	1.90	1.35	1.70	3.05	2.85	2.60	2.45	2.55
12	1.90	2.00	1.85	2.35	1.90	1.40	1.60	6.20	2.70	2.50	2.40	2.50
13	1.90	1.95	1.85	2.25	1.85	2.00	1.90	4.05	2.55	2.45	2.45	2.50
14	1.90	1.95	2.35	2.30	1.85	1.60	4.20	3.50	2.45	2.40	2.95	2.45
15	1.90	1.95	2.80	2.30	1.85	1.50	3.85	3.00	2.40	2.30	2.90	2.40
16	1.90	1.90	2.40	2.25	1.80	1.50	3.55	2.70	2.35	2.25	2.75	2.40
17	1.85	1.90	2.45	2.15	1.80	1.50	2.55	2.35	2.35	2.25	3.00	2.45
18	1.85	1.95	2.35	2.10	1.80	2.40	2.00	3.25	2.25	2.70	3.00	2.45
19	1.85	2.05	2.25	2.05	1.85	2.35	1.80	6.95	2.25	3.35	3.55	2.45
20	2.15	2.00	2.10	2.10	2.10	2.15	1.80	3.60	2.20	2.65	3.40	2.70
21	2.55	2.00	2.05	2.05	1.85	1.80	1.70	3.00	2.20	3.60	2.90	3.00
22	2.35	1.95	2.00	2.00	1.80	1.60	1.65	2.85	2.25	4.45	2.70	3.65
23	2.20	1.95	1.95	2.00	1.80	1.55	9.00	2.55	2.40	3.65	2.70	4.05
24	2.90	1.90	1.95	2.95	1.95	1.55	6.00	2.25	3.45	3.00	2.60	4.85
25	4.90	1.90	1.90	2.75	2.10	1.50	4.20	2.10	2.55	2.65	2.55	3.65
26	5.10	1.85	1.90	2.30	1.80	1.50	3.10	2.45	2.35	2.55	2.50	3.10
27	3.30	1.90	1.90	2.60	1.75	2.30	2.60	2.60	2.25	2.45	2.45	2.80
28	3.05	1.95	1.85	3.30	1.65	1.55	6.40	3.00	2.20	2.40	2.40	2.70
29	2.70	.....	1.95	2.60	1.60	1.50	4.60	2.70	2.20	2.40	2.75	2.65
30	2.50	.....	3.35	2.35	1.60	1.45	2.70	2.50	2.15	2.45	3.00	2.60
31	2.35	.....	4.40	.....	1.60	.....	2.35	2.35	.....	2.40	.....	2.65

ly gage height, in feet, of Oconee River at Cary, Georgia, for 1898. (*a*)

Jan.	Feb.	Mar.	Day.	Jan.	Feb.	Mar.	Day.	Jan.	Feb.	Mar.
2.20	2.70	2.30	12	2.30	2.30	2.30	23	2.40	2.20	2.40
2.10	2.50	2.20	13	2.20	2.30	2.20	24	2.40	2.20	2.40
2.00	2.40	2.20	14	2.20	2.30	2.60	25	2.50	2.20	2.30
2.00	2.40	2.50	15	2.10	2.30	3.50	26	5.00	2.10	2.20
2.10	2.50	2.80	16	2.10	2.30	3.90	27	5.70	2.10	2.20
2.10	2.40	2.70	17	2.10	2.30	3.50	28	4.50	2.10	2.30
2.10	2.40	2.40	18	2.10	2.30	3.90	29	3.50	.....	2.30
2.10	2.40	2.40	19	2.00	2.30	3.10	30	3.00	.....	2.30
2.00	2.40	2.40	20	2.00	2.30	2.60	31	2.80	.....	2.50
2.10	2.40	2.30	21	2.70	2.30	2.40				
2.20	2.40	2.30	22	2.70	2.30	2.50				

a Discontinued March 31.

ily gage height, in feet, of Oconee River at Dublin, Georgia, for 1898.

Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
.....	0.50	1.00	4.00	−0.60	−1.00	5.80	11.80	0.80	3.60	5.50
.....	.50	2.00	2.60	− .70	−1.10	4.30	13.00	.70	3.30	5.50
.....	.50	2.80	1.90	− .70	−1.20	2.80	16.00	2.30	3.10	5.40
.....	.90	2.00	1.70	− .80	−1.20	2.00	23.00	6.90	2.60	7.50
.....	1.90	2.50	1.40	− .90	−1.30	1.60	24.60	8.70	2.30	8.50
.....	3.90	6.00	1.10	−1.00	−1.20	2.00	23.30	9.40	2.10	9.60
.....	3.90	7.80	1.00	− .10	− .90	4.20	21.20	10.50	2.00	11.10
.....	2.60	8.50	.90	− .10	+ .30	5.90	19.50	11.30	2.00	12.60
.....	2.00	9.40	.80	−1.10	1.00	6.40	18.00	13.50	1.80	12.60
.....	1.80	10.00	.70	−1.10	1.80	6.50	17.00	15.50	1.70	10.70
0.90	1.50	9.80	.60	−1.20	1.80	4.20	16.00	16.00	1.70	7.70
.90	1.40	6.50	.60	−1.20	2.80	3.40	14.80	14.50	1.60	6.70
.90	1.00	5.90	.30	−1.20	3.00	3.00	12.50	11.80	1.60	6.00
.90	.90	3.30	.20	−1.20	1.60	4.80	7.60	5.00	3.90	5.60
.90	.90	2.90	.10	− .70	2.90	5.50	4.70	3.90	6.70	5.20
.80	2.00	2.50	.00	− .60	4.60	6.50	3.60	3.50	7.20	4.60
.80	3.50	2.00	.00	− .40	4.00	6.40	3.00	3.20	7.60	4.20
.90	3.50	1.80	− .20	.00	3.20	4.60	3.00	3.00	8.90	4.60
1.00	2.80	1.70	− .20	+ .90	1.80	5.90	2.70	3.00	11.00	3.90
1.50	3.10	1.50	− .30	.80	.90	6.00	2.30	2.80	13.00	4.00
1.50	2.40	1.40	− .30	.60	.50	5.90	2.20	4.30	14.30	4.40
1.40	1.90	1.40	− .40	.80	.00	5.00	2.00	5.60	15.00	5.00
1.10	1.50	1.30	− .40	.70	− .20	3.60	2.00	6.90	14.10	6.10
.90	1.10	1.80	− .40	− .30	+ .10	2.50	1.80	7.50	12.80	6.50
.80	1.00	3.90	− .10	− .50	2.60	1.90	2.00	7.80	10.20	6.90
.70	1.00	5.50	+ .20	− .70	5.10	1.60	2.80	6.30	8.30	6.70
.50	.90	6.00	.80	− .80	6.10	1.90	2.40	4.30	6.20	6.40
.50	.80	4.70	.60	− .90	7.00	7.00	1.50	3.50	5.20	5.60
.....	.70	4.90	− .10	− .90	6.70	10.50	1.20	3.10	5.00	5.20
.....	.60	5.40	− .30	− .90	6.00	10.90	.90	3.00	5.20	4.90
.....	.60	.....	− .50	.....	5.60	11.10	.....	3.30	.....	4.00

ly gage height, in feet, of Ocmulgee River at Macon, Georgia, for 1898.

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
0.50	1.10	0.25	1.75	1.87	−0.53	−0.82	5.11	4.96	0.75	2.54	4.15
.45	1.01	.30	.50	1.10	− .48	− .87	3.70	14.48	.72	2.19	3.51
.38	1.00	.30	.48	.92	− .52	− .35	2.11	16.60	7.72	2.08	9.40
.32	.70	1.08	.60	.78	− .58	− .50	1.85	18.22	16.85	2.00	13.60
.32	.69	3.35	4.33	.60	− .70	− .78	10.50	15.76	17.32	1.85	9.72
.38	.71	3.30	12.10	.50	− .78	− .90	10.76	14.72	15.15	1.92	8.10
.45	.77	1.45	10.13	.58	− .82	+2.12	10.79	11.00	13.35	2.90	6.61
.43	.75	1.35	7.90	.58	− .87	1.35	8.72	9.40	11.75	2.03	6.03
.41	.67	1.10	4.37	.47	− .80	1.93	4.91	6.90	9.21	1.90	5.21
.43	.60	.80	3.92	.30	− .83	3.48	2.70	6.11	7.35	1.83	5.80
.58	.60	.75	2.90	.21	− .94	3.62	6.31	4.00	5.02	2.91	4.21
.75	.52	.60	2.74	.18	− .95	1.22	12.70	3.65	4.10	3.37	3.64
1.63	.50	.60	2.10	.20	− .96	.90	13.00	3.80	3.50	4.22	3.60
1.30	.48	.60	1.75	.18	+ .10	1.20	12.97	2.80	3.07	6.41	3.42
90	.36	2.00	1.60	.10	.53	3.20	9.12	2.50	2.85	6.23	3.21
.94	.32	3.92	1.50	.04	− .10	3.80	6.52	1.93	2.56	14.10	2.91
.83	.25	3.00	1.20	− .08	− .10	2.67	4.92	1.89	2.30	10.21	2.80
.76	.40	2.02	.98	− .15	− .38	1.60	5.41	1.72	4.12	9.27	2.77
.60	.63	1.49	.85	− .20	+ .11	.70	2.70	1.56	4.38	12.31	3.11
.66	.72	1.22	1.02	− .10	.83	.20	4.10	1.30	4.18	9.02	3.00
1.45	.64	.95	1.60	− .15	.60	− .11	2.10	1.22	5.21	6.95	4.10
1.85	.50	.85	1.32	+ .05	2.21	− .28	1.94	1.48	6.90	5.50	5.67
1.56	.40	.75	1.30	.11	.20	− .32	1.90	1.42	5.23	5.15	5.60
1.10	.33	.50	7.95	.91	− .41	+3.32	1.42	1.35	4.17	4.31	5.52
1.22	.29	.50	8.90	1.52	− .50	2.51	.90	1.31	3.94	4.00	4.91
2.70	.25	.45	6.12	1.46	− .53	5.35	.50	1.28	3.20	3.50	4.60
5.37	.23	.39	3.15	1.10	+ .30	5.30	4.25	1.12	2.91	3.18	4.07
4.31	.22	.36	2.90	.32	.51	3.10	7.21	.98	2.43	2.92	3.80
2.50	.....	.39	2.55	− .11	− .42	3.14	9.45	.83	2.32	3.50	3.30
2.08	.....	.50	2.05	− .30	− .65	4.30	7.53	.77	2.90	3.31	3.21
1.62	.....	1.50	.....	− .36	.....	9.02	5.08	.....	2.71	.....	3.10

List of discharge measurements.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
				Feet.	*Sec.-feet.*
1898.					
Feb. 26	Roanoke River	Roanoke, Va	D. C. Humphreys	0.94	132
May 7	do	do	do	3.75	3,445
July 20	do	do	do	.95	113
Jan. 8	Dan River	Clarksville, Va	E. W. Myers	1.05	2,009
Feb. 26	Staunton River	do	do	.70	1,969
Jan. 11	Roanoke River	Neal, N. C	do	4.43	4,334
May 10	do	do	do	22.50	27,880
Jan. 13	Tar River	Tarboro, N. C	do	2.30	1,323
May 10	do	do	do	7.30	3,757
Jan. 9	Neuse River	Selma, N. C	do	1.20	426
Aug. 31	do	do	do	6.85	2,908
May 6	Haw River	Moncure, N. C	do	1.56	495
Aug. 19	do	do	do	15.40	7,925
May 6	Deep River	do	do	2.00	403
Aug. 20	do	do	do	17.20	14,994
Jan. 10	Cape Fear River	Fayetteville, N. C	do	3.55	1,308
Aug. 22	do	do	do	28.35	23,215
Jan. 17	Yadkin River	Salisbury, N. C	do	2.10	2,567
April 1	do	do	do	3.90	9,110
Aug. 13	do	do	do	5.05	11,237
Jan. 16	Yadkin (Pedee) River.	Norwood, N. C	do	1.63	3,041
Mar. 31	do	do	do	5.75	24,825
Jan. 14	Catawba River	Catawba, N. C	do	2.01	1,228
Jan. 25	do	Rockhill, S. C	do	3.20	7,732
Oct. 26	do	do	do	3.50	7,108
Jan. 26	Broad River	Gaffney, S. C	do	2.67	3,052
Oct. 27	do	Alston, S. C	do	4.60	5,687
Jan. 23	Saluda River	Waterloo, S. C	do	4.65	1,350
Oct. 27	do	do	do	5.10	1,684
May 25	Tugalo River	Madison, S. C	Max Hall	1.50	902
June 9	do	do	do	.90	563
July 19	do	do	do	2.05	1,100
Oct. 28	do	do	do	4.00	2,439
Apr. 16	Savannah River	Calhoun Falls, S. C	do	2.75	4,081
1896.					
Oct. 3	do	Augusta, Ga	B. M. Hall	5.41	3,154
1897.					
July 15	do	do	do	6.67	4,198
Sept. 29	do	do	do	5.17	3,180
Nov. 6	do	do	Max Hall	6.20	4,311
1898.					
Apr. 28	do	do	do	11.55	14,494
June 16	do	do	B. M. Hall	5.25	3,393
July 27	do	do	do	9.85	11,380
July 28	do	do	do	10.37	14,280
Aug. 2	do	do	Knox T. Thomas	7.17	6,392
Aug. 3	do	do	do	6.72	5,511
Sept. 3	do	do	B. M. Hall	28.27	87,472
Sept. 16	do	do	Warren Hall	8.10	7,432
Sept. 17	do	do	do	8.00	7,108
Nov. 14	do	do	Jas. C. Conn	11.66	13,243
Jan. 29	Broad River	Carlton, Ga	Max Hall	2.68	995
Feb. 21	do	do	do	2.00	577
Apr. 20	do	do	do	2.10	667
June 14	do	do	do	1.56	398
July 25	do	do	do	3.75	2,165
Sept. 13	do	do	B. M. Hall	2.50	930
Oct. 8	do	do	do	3.05	1,446
Mar. 22	Oconee River	Cary, Ga	Max Hall	2.50	1,168
Nov. 15	do	do	Jas. C. Conn	3.65	2,386
Feb. 11	do	Dublin, Ga	Max Hall	.95	2,057
Mar. 29	do	do	do	.65	1,927
May 20	do	do	do	—.23	1,272
June 24	do	do	do	.28	1,164
July 27	do	do	do	6.23	7,007
Aug. 30	do	do	do	10.80	12,161
Oct. 20	do	do	B. M. Hall	3.70	4,153
Jan. 7	Ocmulgee River	Macon, Ga	Max Hall	.42	889
Feb. 10	do	do	do	.60	1,010
Mar. 28	do	do	do	.36	976
Mar. 30	do	do	do	.50	1,028
May 19	do	do	do	—.20	687
June 23	do	do	do	—.34	620
July 26	do	do	do	4.92	3,218
July 27	do	do	do	5.65	3,709
Aug. 29	do	do	do	9.25	6,125
Aug. 30	do	do	do	7.20	4,477
Oct. 19	do	do	B. M. Hall	4.50	3,111
Nov. 5	do	do	Jas. C. Conn	1.90	1,474

List of miscellaneous discharge measurements, 1898.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
				Feet.	*Sec.-feet.*
Jan. 12	Amicalola River	Heards Mill, Hollensheds Bridge, Ga.	Max Hall	1.40	273
Jan. 13	Ellijay River	Ellijay, Ga	do	1.00	262
Do	Cartecay River	do	do	1.20	428
Feb. 12	East Long Swamp Creek.	Marble Hill, Ga	B. M. Hall		20
Apr. 19	Chattahoochee River.	Near Gainesville, Shallow Ford Bridge, Ga.	do	1.20	844
May 26	Choccolocco Creek.	Eureka, Alabama.	do	1.08	171
May 28	Peachtree Creek	At mouth, from first wagon bridge, Oakdale, Ga.	do	*a* .30	36
Do	Proctor Creek	Mouth, one-fourth mile below Oakdale, Ga.	do	*a* .30	7
June 16	Hiwassee River	Reliance, Tenn	Max Hall	2.84	954
June 23	Long Swamp Creek	Revis Bridge, in Cherokee County, Ga.	B. M. Hall		50
June 25	Amicalola River	Hills Ford, Dawson County, Ga.	do		112
Do	Talking Rock Creek.	Near Carters, Ga.	Olin P. Hall	*a* 1.12	55
July 7	Peachtree Creek	At mouth, first wagon bridge.	Warren Hall	*a* 1.15	31
Do	do	do	do	*a* 1.10	33
Aug. 19	Vickerys Creek	Near Roswell, Ga	B. M. Hall	2.00	129
Aug. 25	Talking Rock Creek.	Carters, Ga	Max Hall	*a* 1.70	79
Dec. 20	Silver Spring	Near Ocala, Fla	do		822
Dec. 21	Kissingen Spring	Bartow, Fla	do		31
Dec. 22	Blue Spring	Juliet, Fla	do		778
Dec. 23	Itchatucknee Spring.	Near Fort White, Fla.	do		408
Oct. 25	Broad River	Blacksburg, S. C	E. W. Myers	2.90	2,999

a At river station.

Rating tables.

Neal.		Fayetteville.		Catawba.		Rockhill.		Alston.	
Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*
0.0	1,750	1.0	489	1.5	750	1.0	1,800	1.0	1,560
.5	1,900	2.0	810	2.0	1,425	1.5	2,610	1.5	1,700
1.0	2,060	3.0	1,187	2.5	2,175	2.0	3,700	2.0	1,900
1.5	2,225	4.0	1,674	3.0	3,050	2.5	5,000	2.5	2,250
2.0	2,410	5.0	2,210	3.5	4,135	3.0	6,350	3.0	2,850
2.5	2,585	6.0	2,740	4.0	5,400	3.5	7,800	3.5	3,620
3.0	2,775	7.0	3,280	4.5	6,780	4.0	9,300	4.0	4,490
3.5	2,975	8.0	3,822	5.0	8,225	4.5	10,800	4.5	5,490
4.0	3,200	9.0	4,382	5.5	9,700	5.0	12,400	5.0	6,490
4.5	3,430	10.0	4,955	6.0	11,175	5.5	14,200	5.5	7,490
5.0	3,660	11.0	5,535	6.5	12,650	6.0	16,000	6.0	8,530
5.5	3,910	12.0	6,133	7.0	14,125	6.5	18,000	6.5	9,590
6.0	4,185	13.0	6,733	7.5	15,600	7.0	20,000	7.0	10,700
6.5	4,460	14.0	7,333	8.0	17,075	7.5	22,500	7.5	11,850
7.0	4,750	15.0	7,933	8.5	18,550	8.0	25,000	8.0	13,000
8.0	5,450	16.0	8,541	9.0	20,025	8.5	27,500	8.5	14,150
9.0	6,250	17.0	9,161	9.5	21,500	9.0	30,000	9.0	15,300
10.0	7,200	18.0	9,781	10.0	22,975	9.5	32,500	9.5	16,450
11.0	8,200	19.0	10,401	10.5	24,450	10.0	35,000	10.0	17,600
12.0	9,300	20.0	11,569	11.0	25,925	10.5	37,500	11.0	20,000
13.0	10,600	21.0	12,928	12.0	28,875	11.0	40,000	12.0	22,500
14.0	12,000	22.0	14,287	13.0	31,825	11.5	42,750	13.0	25,000
15.0	13,500	23.0	15,646	14.0	34,775	12.0	45,500	14.0	27,500
16.0	15,075	24.0	17,005	15.0	37,725	12.5	49,550	15.0	30,000
17.0	16,700	25.0	18,364	16.0	40,675	13.0	53,600	16.0	32,500
18.0	18,400	26.0	19,723	17.0	43,630	13.5	57,700	17.0	35,000
20.0	22,400	27.0	21,082	18.0	46,650	14.0	61,800	18.0	37,500
22.0	27,850	28.0	22,441	19.0	49,650	14.5	65,900	19.0	40,000
24.0	34,650	29.0	23,800	20.0	52,650	15.0	70,000	20.0	42,500
28.0	64,300	*30.0*	*25,159*	*21.0*	55,650	15.5	74,100	22.0	47,500

Rating tables—Continued.

Waterloo.		Madison.		Calhoun Falls.		Augusta.	
Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*
1.9	290	0.9	563	1.7	1,450	3.0	2,000
2.0	300	1.0	615	1.8	1,580	3.5	2,150
2.1	310	1.2	715	1.9	1,720	4.0	2,350
2.2	320	1.4	815	2.0	1,875	5.0	3,100
2.3	335	1.6	920	2.1	2,045	6.0	4,020
2.4	350	1.8	1,030	2.2	2,225	7.0	5,400
2.5	375	2.0	1,140	2.3	2,445	8.0	7,200
2.6	400	2.2	1,260	2.4	2,680	9.0	9,340
2.7	430	2.4	1,380	2.5	2,940	10.0	11,800
2.8	465	2.6	1,500	2.6	3,240	11.0	14,620
2.9	505	2.8	1,620	2.7	3,590	12.0	17,750
3.0	550	3.0	1,740	2.8	4,000	13.0	21,100
3.2	630	3.2	1,874	2.9	4,500	14.0	25,000
3.4	715	3.4	2,008	3.0	5,000	15.0	29,300
3.6	805	3.6	2,148	3.1	5,500	16.0	33,600
3.8	900	3.8	2,294	3.2	6,000	17.0	38,000
4.0	1,000	4.0	2,440	3.3	6,500	18.0	42,400
4.2	1,105	4.2	2,598	3.4	7,000	19.0	46,800
4.4	1,215	4.4	2,756	3.5	7,500	20.0	51,200
4.6	1,330	4.6	2,914	3.6	8,000	21.0	55,600
4.8	1,450	4.8	3,072	3.7	8,500	22.0	60,000
5.0	1,575	5.0	3,230	3.8	9,000	23.0	64,400
5.2	1,705	5.5	3,625	3.9	9,500	24.0	68,800
5.4	1,840	6.0	4,020	4.0	10,000	25.0	73,200
5.6	1,980	6.5	4,415	4.2	11,000	26.0	77,600
5.8	2,130	7.0	4,810	4.4	12,000	27.0	82,000
6.0	2,280	7.5	5,205	4.6	13,000	28.0	86,400
7.0	3,030	8.0	5,600	4.8	14,000	.....	.....
8.0	3,830	.....	.....	5.0	15,000	.....	.....
9.0	4,730	.....	.....	.....	.....	.....	.....

Carlton.		Cary.		Dublin.		Macon.	
Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*
1.4	320	0.0	240	−1.2	890	−1.0	370
1.6	385	.2	260	−1.0	950	− .5	545
1.8	480	.4	290	− .5	1,140	.0	740
2.0	577	.6	320	.0	1,425	.5	940
2.2	700	.8	350	.5	1,746	1.0	1,150
2.4	850	1.0	380	1.0	2,080	1.5	1,380
2.6	1,030	1.2	415	1.5	2,429	2.0	1,630
2.8	1,215	1.4	470	2.0	2,790	2.5	1,905
3.0	1,405	1.6	560	2.5	3,166	3.0	2,180
3.5	1,894	1.8	675	3.0	3,560	3.5	2,455
4.0	2,384	2.0	815	3.5	3,980	4.0	2,730
4.5	2,874	2.2	970	4.0	4,460	4.5	3,005
5.0	3,364	2.4	1,144	4.5	4,998	5.0	3,280
5.5	3,854	2.6	1,320	5.0	5,560	5.5	3,555
6.0	4,344	2.8	1,496	5.5	6,130	6.0	3,830
6.5	4,834	3.0	1,672	6.0	6,700	6.5	4,110
7.0	5,324	3.2	1,848	6.5	7,270	7.0	4,410
7.5	5,814	3.4	2,024	7.0	7,840	7.5	4,715
8.0	6,304	3.6	2,200	7.5	8,410	8.0	5,060
8.5	6,794	3.8	2,376	8.0	8,980	8.5	5,440
9.0	7,284	4.0	2,554	8.5	9,550	9.0	5,880
9.5	7,774	4.2	2,750	9.0	10,120	10.0	6,900
10.0	8,264	4.4	2,965	9.5	10,690	11.0	8,800
10.5	8,754	4.6	3,200	10.0	11,260	12.0	11,800
.....	.....	4.8	3,450	11.0	12,400	13.0	15,000
.....	.....	5.0	3,750	12.0	13,540	14.0	18,200
.....	.....	5.2	4,080	13.0	14,680	15.0	21,400
.....	.....	5.4	4,500	14.0	15,820	16.0	24,600
.....	.....	5.6	4,950	15.0	16,960	17.0	27,800
.....	.....	5.8	5,410	16.0	18,100	18.0	31,000

EASTERN GULF DRAINAGE.

DESCRIPTION OF RIVER STATIONS.

Molina station on Flint River.—Described on page 45 of Paper No. 15. Results for 1897 shown on pages 233–234 of the Nineteenth Annual Report, Part IV. The alternate accumulation and washing out of sediment in an eddy half a mile below so affected the gage heights that it has not been possible to establish a definite relation between them and the discharge measurements of 1897 and 1898. Prof. B. M. Hall has constructed a rating table by averaging the conflicting measurements that were made at or near the same gage heights. This is the best that can be done with the data in hand. A new station will be established as soon as a proper section can be found.

Albany station on Flint River.—This station is maintained by the United States Weather Bureau. The drainage area is approximately 5,000 square miles. The observer is John E. Clark. No discharge measurements were made during 1898. Mr. J. B. Marbury, the local forecast official at Atlanta, Georgia, furnishes the following information: The river gage is in two sections. The long section, from 10 to 36 feet, is nailed in two segments to the south face, downstream side of the west pier on the right or Albany side of river. The short section is nailed to a cypress tree 120 feet down the river from pier. The top of the pier-foundation sill is 8.1 feet above low water. A second gage, reading from zero to 21 feet, is nailed to a cypress tree on left-hand bank of river, about 100 feet downstream from the point where the south side of Commerce street, if extended, would cross the river. The first bench mark is the top of the white marble foundation stone of the A. M. E. Church, corner of Washington and State street, Albany, Georgia. It is 49.5 feet above zero of gage. The second bench mark is the top of the sill of the old wharf at the foot of Broad street. It is 3 feet above low water.

Oakdale station on Chattahoochee River.—Described on page 46 of Paper No. 15. Results for 1897 shown on page 235 of the Nineteenth Annual Report, Part IV. On July 1 the station was moved to Mason and Turner's Ferry, 1 mile below Oakdale. The observer is C. H. Turner. The gage at this point, known as Oakdale lower gage, is nailed to a tree on the right bank, 100 yards below the ferry, and is set 1 foot deeper in the water than the gage at the Southern Railroad Bridge.

West Point station on Chattahoochee River.—Described on page 47 of Paper No. 15. Results for 1897 are shown on page 237 of the Nineteenth Annual Report, Part IV.

Canton station on Etowah River.—Described on page 48 of Paper No. 15. Results for 1897 shown on page 242 of the Nineteenth Annual

Report, Part IV. The zero of gage is 881.02 feet above sea level, as given in Report of United States Weather Bureau, Daily River Stages on the principal rivers of the United States, Part IV, 1893.

Carters station on Coosawattee River.—Described on page 49 of Paper No. 15; results for 1897 shown on page 243 of the Nineteenth Annual Report, Part IV. The observer for 1898 was H. S. Weems.

Resaca station on Oostanaula River.—Described on page 50 of Paper No. 15; results for 1897 given on page 245 of the Nineteenth Annual Report, Part IV.

Rome station on Coosa River.—Coosa River is formed by the junction of Etowah and Oostanaula rivers at Rome, Georgia. Measurements of discharge are made on each of these tributaries. The Etowah River is measured at Second Avenue Bridge and Oostanaula River at Fifth Avenue Bridge, and the results added to give the flow of Coosa River, the junction being a short distance below these bridges. The gage height is taken from the Weather Bureau gage at Fifth Avenue Bridge, on the Oostanaula. There is practically no fall on the Oostanaula River from Fifth Avenue Bridge to the junction, hence the gage is used as Coosa River gage, and gives the fluctuations of Coosa River. This gage is 4 by 6 timber, graduated to feet and tenths, and fastened to the downstream left-hand corner of the first pier from left bank. The zero of gage is 575.79 above sea level. The United States Weather Bureau has maintained a station here for many years. It is now maintained only as a half-year station, from November 1 to April 30, inclusive, but W. M. Towers, the river observer, feels so much personal interest in the matter that he reads the gage during the other six months without compensation, and kindly furnishes the Survey with monthly reports of the daily gage heights for the entire year without charge. Mr. Towers has kept the record for many years, and has predicted floods with great precision.

Riverside station on Coosa River, including locks Nos. 4 and 5.—Described on page 51 of Paper No. 15; results for 1897 given on page 246 of the Nineteenth Annual Report, Part IV.

Wetumpka station on Coosa River.—Described on page 54 of Paper No. 15, and on page 241 of the Nineteenth Annual Report, Part IV.

Milstead station on Tallapoosa River.—Described on page 56 of Paper No. 15; results for 1897 shown on page 249 of the Nineteenth Annual Report, Part IV. This station was established by B. M. Hall August 7, 1897.

Tuscaloosa station on Black Warrior River.—Described on page 57 of Paper No. 15; results for 1897 shown on page 250 of the Nineteenth Annual Report, Part IV. The observer since April 16, 1898, has been R. C. McCalla, jr., United States assistant engineer.

TABLES OF DAILY GAGE HEIGHT.

Daily gage height, in feet, of Flint River at Molina, Georgia, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	Day.	Jan.	Feb.	Mar.	Apr.	May.	June.
1	1.95	2.10	1.80	2.25	1.85	1.05	17	2.10	1.80	2.55	1.85	1.20	.....
2	1.90	2.00	1.80	2.10	1.75	a1.10	18	2.05	1.90	2.40	1.75	1.20	.....
3	1.80	2.00	1.85	1.95	1.65	.....	19	1.95	2.05	2.25	1.70	1.15	.....
4	1.75	1.90	2.40	1.85	1.60	.....	20	2.00	2.05	2.10	1.80	1.20	.....
5	1.85	1.90	2.80	4.00	1.50	.....	21	2.10	2.00	2.00	1.90	1.15	.....
6	1.85	1.90	2.60	5.50	1.45	.....	22	2.30	1.95	1.95	1.90	1.15	.....
7	1.90	1.90	2.40	4.10	1.45	.....	23	2.30	1.90	1.90	1.80	1.15	.....
8	1.95	1.90	2.20	3.50	1.40	.....	24	2.20	1.85	1.80	3.80	1.45	.....
9	2.05	1.90	2.10	2.90	1.40	.....	25	2.10	1.85	1.80	3.35	1.80	.....
10	2.00	1.95	2.00	2.55	1.35	.....	26	2.40	1.80	1.70	3.35	1.60	.....
11	1.90	1.90	1.95	2.25	1.30	.....	27	2.60	1.80	1.70	3.05	1.45	.....
12	2.05	1.95	1.90	2.10	1.30	.....	28	2.60	1.80	1.70	2.50	1.30	.....
13	2.20	1.90	1.90	2.05	1.35	.....	29	2.45	.....	1.70	2.20	1.20	.....
14	2.30	1.90	2.10	2.05	1.30	.....	30	2.30	.....	1.90	2.05	1.10	.....
15	2.20	1.90	2.75	2.00	1.30	.....	31	2.20	.....	2.40	.....	1.00	.....
16	2.25	1.85	2.70	1.90	1.30	.....							

a Discontinued.

Daily gage height, in feet, of Flint River at Albany, Georgia, for 1897. (a)

Day.	Feb.	Mar.	Apr.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.7	9.4	.....	1.3	1.6	2.2	1.5	0.9	1.1
2	3.9	11.5	.....	1.5	1.4	2.0	1.5	.9	1.4
3	4.3	12.4	13.8	1.6	1.2	2.0	1.6	.9	1.5
4	5.7	11.8	13.8	1.0	1.1	2.2	1.7	1.1	1.6
5	6.5	10.0	13.7	1.0	1.0	1.9	1.5	1.5	1.5
6	6.7	8.9	14.2	1.7	1.0	1.7	1.5	1.4	1.5
7	7.2	7.6	14.7	4.2	.9	1.6	1.4	1.3	1.6
8	7.5	8.7	15.1	5.5	1.2	1.5	1.2	1.1	1.6
9	8.3	9.0	15.2	5.7	1.4	1.5	1.2	1.1	1.6
10	9.2	9.0	16.5	5.1	2.4	1.5	1.1	1.1	1.7
11	10.0	10.0	17.9	3.0	2.5	1.4	1.0	1.1	1.7
12	11.5	11.0	17.9	2.5	2.6	1.3	.8	1.2	1.6
13	12.2	11.8	17.9	3.2	2.7	1.3	1.0	1.2	1.6
14	13.0	12.3	16.1	4.2	2.5	1.6	1.0	1.3	1.7
15	14.1	11.6	14.7	5.3	1.7	1.7	1.1	1.2	2.0
16	16.5	10.8	13.1	5.1	1.4	1.9	1.2	1.2	2.6
17	17.8	10.4	10.6	3.2	2.6	2.0	1.2	1.1	2.6
18	19.6	14.9	9.1	2.8	2.2	1.8	1.3	1.3	2.6
19	19.0	19.8	9.1	2.0	2.8	1.6	1.1	1.1	2.7
20	16.4	22.8	8.9	1.7	3.6	1.8	1.1	1.1	2.8
21	15.0	22.7	8.9	2.0	4.1	1.8	1.0	1.2	2.9
22	13.0	22.7	8.9	2.4	5.1	1.6	1.0	1.1	2.9
23	11.0	24.1	8.3	3.6	6.8	1.5	1.2	1.1	3.2
24	10.4	28.7	6.1	4.2	6.3	1.5	1.4	1.3	2.9
25	9.0	31.6	5.1	5.3	6.5	1.4	1.2	1.2	2.9
26	8.9	30.9	4.7	4.9	7.0	1.3	1.2	1.1	2.8
27	7.1	28.0	3.7	3.7	7.2	1.1	1.0	1.1	2.6
28	6.9	26.5	3.7	2.0	6.7	1.1	.8	.9	2.3
29	.....	25.5	3.4	1.9	4.1	1.1	.9	.9	2.3
30	.....	23.6	3.4	1.8	3.2	1.3	.9	1.1	2.3
31	.....	21.3	.....	1.7	2.2	.....	.9	.....	2.3

a No records for May or June.

Daily gage height, in feet, of Flint River at Albany, Georgia, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.9	2.2	1.7	1.2	4.3	1.6	3.7	3.4	16.0	0.8	2.0	6.1
2	1.9	2.0	1.6	1.4	3.7	1.4	3.6	4.0	17.2	.8	2.0	7.4
3	1.8	1.9	1.9	1.3	2.9	1.0	3.4	5.8	16.3	1.0	2.00	8.2
4	1.7	1.9	2.2	1.3	2.6	.9	3.4	6.4	15.1	2.0	1.7	9.6
5	1.6	1.9	2.8	1.2	2.3	.8	3.0	7.0	14.3	5.4	1.4	10.3
6	1.6	2.1	3.2	2.3	2.0	.6	3.0	6.7	13.0	6.5	1.4	9.4
7	1.6	2.0	3.7	3.6	1.8	.5	2.6	6.8	12.2	7.8	1.3	9.6
8	1.6	1.8	4.0	5.2	1.8	.5	2.5	7.5	10.3	9.5	1.2	9.8
9	1.7	1.8	4.0	6.1	1.6	.5	2.4	8.0	9.6	10.5	1.4	10.3
10	1.8	1.8	3.2	7.0	1.6	.5	2.4	8.4	10.5	12.0	1.6	11.1
11	1.8	1.7	2.8	6.1	1.6	.6	2.3	8.3	10.8	12.0	2.2	12.0
12	1.9	1.7	2.4	5.0	1.4	.7	2.4	7.6	10.8	10.1	2.6	11.5
13	1.9	1.7	2.2	4.6	1.3	.7	2.6	5.3	10.8	8.8	3.4	10.3
14	1.9	1.7	2.1	3.9	1.3	.7	3.0	5.7	8.6	8.8	3.6	9.4
15	2.0	1.5	1.9	3.6	1.2	.8	3.5	6.1	6.9	8.1	4.2	8.5
16	2.2	1.5	1.9	3.2	1.2	.9	4.0	7.4	5.1	7.2	5.7	7.8
17	1.6	1.4	1.9	2.0	1.2	.9	4.5	8.9	4.0	6.6	7.2	6.7
18	1.8	1.8	2.3	1.9	1.1	.9	4.6	9.9	3.6	6.6	8.7	5.4
19	1.9	2.0	2.6	1.9	1.1	.9	4.6	9.7	3.0	7.0	10.2	4.6
20	2.2	1.8	2.7	1.8	1.0	1.2	4.4	8.9	2.7	7.3	12.5	5.5
21	2.3	1.6	2.4	1.6	1.0	1.4	4.2	7.3	2.7	7.6	13.8	6.3
22	2.3	2.0	2.1	2.0	1.0	2.0	4.0	5.0	2.6	7.0	15.6	7.4
23	2.3	2.3	2.0	2.0	1.1	2.6	3.8	4.5	2.5	6.0	16.1	8.0
24	2.2	2.2	1.8	2.0	1.2	3.0	3.8	3.6	2.3	5.2	15.3	8.0
25	2.2	2.0	1.7	2.6	1.2	3.0	3.5	2.8	2.3	4.6	13.0	8.0
26	2.2	1.9	1.6	3.0	1.6	3.1	3.3	2.0	2.0	4.2	13.0	7.7
27	2.3	1.7	1.5	3.9	1.7	3.2	3.0	2.9	1.7	3.0	12.0	7.35
28	2.3	1.7	1.5	4.6	1.8	3.4	2.8	6.1	1.4	2.5	10.2	7.25
29	2.1	.....	1.3	5.4	1.8	3.5	2.6	10.5	1.0	2.0	8.0	7.0
30	2.0	.....	1.2	5.4	1.8	3.6	2.4	13.1	.8	2.0	6.7	6.[illegible]
31	2.1	.....	1.2	.....	1.9	.....	2.8	14.0	.....	2.0	.....	6.[illegible]

Daily gage height, in feet, of Chattahoochee River at Oakdale, Georgia, for 18[illegible]

Day.	Upper gage.						Lower gage.					
	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	0.75	1.50	0.40	5.50	1.85	0.25	0.95	2.30	3.10	2.40	3.10	3.70
2	.55	1.30	.40	3.45	1.60	.30	1.10	2.00	20.00	2.50	3.00	3.40
3	.55	1.05	.55	2.60	1.55	.25	.75	1.90	27.75	2.90	2.90	3.60
4	.50	1.00	.80	3.05	1.45	.20	.70	8.50	27.00	15.00	3.00	4.10
5	.55	.95	.85	8.70	1.35	.09	1.40	14.00	22.00	19.25	3.10	5.50
6	.55	1.00	.70	11.15	1.20	.03	1.10	16.00	15.00	23.50	3.80	4.75
7	.55	.95	.55	5.80	1.20	.00	1.85	9.00	12.00	16.25	3.50	4.10
8	.60	.80	.45	3.80	1.10	— .05	3.70	6.00	7.50	7.50	3.30	3.75
9	.65	.75	.35	2.95	1.10	— .02	5.10	3.80	5.50	6.50	2.90	3.40
10	.55	.70	.30	2.35	.90	— .10	4.75	4.30	5.10	5.50	2.80	3.10
11	.55	.70	.30	2.30	.90	— .13	3.50	4.50	4.75	4.90	3.10	3.00
12	.55	.70	.30	2.00	.90	— .20	2.30	5.80	4.00	4.50	3.80	3.30
13	.85	.65	.30	1.75	1.20	.00	1.85	4.10	4.20	4.30	3.10	3.10
14	1.25	.65	.50	1.75	.95	.13	2.50	7.50	3.90	4.00	3.60	2.95
15	1.00	.55	1.05	1.90	.85	.08	4.20	5.50	3.75	3.90	4.10	2.90
16	.85	.55	1.40	1.60	.80	.93	4.10	2.90	3.60	3.70	3.60	2.80
17	.80	.45	3.50	1.45	.70	— .05	2.50	2.85	3.40	3.50	3.70	2.75
18	.75	.60	1.75	1.30	.65	+1.50	1.85	2.40	3.30	5.70	4.05	2.85
19	.75	.90	1.50	1.15	.60	1.65	1.75	2.90	3.20	7.90	4.75	2.95
20	.90	1.05	1.05	1.20	.60	1.53	1.50	6.00	3.10	4.70	5.10	3.25
21	1.50	.75	.85	1.40	.60	1.75	1.40	6.50	3.30	4.30	4.50	3.95
22	2.30	.75	.75	1.35	.55	.35	1.45	4.50	2.90	4.90	3.75	3.50
23	1.50	.55	.55	1.40	1.20	.10	1.50	3.90	3.10	5.30	3.50	7.10
24	1.35	.55	.45	3.65	1.15	— .05	12.40	2.80	5.30	4.10	4.75	8.50
25	2.95	.45	.40	4.55	1.25	— .15	6.30	2.75	3.25	3.80	3.75	5.75
26	7.70	.40	.40	2.65	.80	— .15	3.40	2.90	2.95	3.50	3.50	4.10
27	6.80	.45	.40	2.25	.80	— .20	3.80	7.50	2.80	3.40	3.30	3.75
28	5.05	.60	1.15	2.85	.60	— .05	6.40	4.30	2.70	3.45	3.10	3.50
29	4.35	.....	2.50	2.35	.30	— .07	5.85	2.80	2.60	3.30	3.75	2.95
30	3.05	.....	6.30	1.85	.30	.10	4.40	3.20	2.50	3.45	4.05	2.75
31	2.70	.....	8.40	.....	.25	.....	3.75	3.20	.....	3.30	.....	3.10

Daily gage height, in feet, of Coosawattee River at Carters, Georgia, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.20	2.00	1.40	2.90	2.05	1.20	0.95	2.00	2.00	1.40	2.05	2.50
2	1.10	2.00	1.40	2.90	2.00	1.20	.90	2.05	13.20	1.60	2.00	2.40
3	1.00	2.00	1.30	2.90	1.95	1.10	.90	2.00	11.50	1.75	2.00	2.00
4	1.00	1.95	1.30	3.00	1.90	1.10	.90	2.10	7.00	20.50	2.00	1.90
5	1.00	1.95	1.20	13.50	1.80	1.10	1.00	2.00	5.00	23.00	1.90	1.80
6	.90	1.90	1.10	7.00	1.80	1.05	1.10	2.15	4.00	11.50	2.00	1.70
7	.90	1.90	1.10	5.00	1.80	1.05	1.05	1.95	3.20	5.00	1.90	1.70
8	.95	1.80	1.10	4.20	1.70	1.00	1.10	2.00	3.00	3.50	1.90	1.60
9	.95	1.80	1.05	3.50	1.70	1.00	1.10	2.00	2.50	3.00	1.80	1.70
10	1.10	1.80	1.00	3.00	1.60	1.05	1.00	2.25	2.20	3.90	1.70	1.50
11	1.50	1.70	1.00	2.30	1.60	1.00	1.00	4.70	2.00	2.80	1.80	1.60
12	2.00	1.70	1.05	2.00	1.50	1.10	1.10	3.50	1.90	2.60	1.90	1.60
13	2.50	1.60	1.10	2.00	1.50	1.40	1.10	3.00	1.80	2.40	2.00	1.70
14	2.00	1.60	2.00	1.90	1.45	1.60	1.30	2.50	1.50	2.30	2.10	1.70
15	1.80	1.60	1.90	2.05	1.45	1.70	1.40	2.25	1.40	2.30	2.05	1.60
16	1.80	1.55	1.80	2.10	1.40	1.60	1.10	2.10	1.30	2.20	2.00	1.80
17	1.70	1.55	1.80	2.10	1.40	1.60	1.20	2.50	1.20	2.20	1.90	1.90
18	1.70	1.50	1.70	2.10	1.40	1.50	1.10	3.00	1.25	4.70	1.90	1.80
19	3.05	1.50	1.70	2.05	1.30	1.80	1.10	2.50	1.30	3.20	2.00	1.70
20	2.30	1.50	1.60	2.10	1.30	2.00	1.05	2.30	1.30	3.00	1.90	1.70
21	2.10	1.45	1.60	2.05	1.30	1.80	1.00	9.50	1.20	2.50	1.80	1.80
22	2.50	1.30	1.50	2.00	1.35	1.70	1.00	3.00	1.20	2.50	2.50	2.00
23	2.50	1.30	1.40	2.50	1.35	1.40	1.10	2.00	1.25	2.50	2.40	2.10
24	2.10	1.20	1.40	3.50	1.40	1.20	1.10	1.60	1.30	2.50	2.40	2.00
25	8.00	1.20	1.60	4.00	1.60	1.05	1.20	1.80	1.20	2.40	2.50	2.00
26	6.10	1.20	1.60	3.00	1.50	1.00	1.30	1.60	1.20	2.40	2.30	1.90
27	3.50	1.50	1.50	2.20	1.50	1.00	1.50	1.50	1.20	2.30	2.40	1.90
28	2.80	1.50	1.50	2.20	1.50	1.05	3.50	1.50	1.20	2.30	2.50	1.80
29	2.50	.....	3.50	2.10	1.40	.90	2.50	1.50	1.30	2.20	2.80	1.70
30	2.50	.....	6.50	2.10	1.30	.95	2.00	1.60	1.30	2.10	2.70	1.70
31	2.10	.....	4.00	.....	1.25	.....	3.00	1.80	.....	2.10	.....	1.80

Daily gage height, in feet, of Oostanaula River at Resaca, Georgia, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.10	5.15	3.10	10.05	4.50	2.65	1.90	5.90	2.65	2.70	3.65	5.30
2	2.95	4.60	2.90	7.00	4.25	2.30	2.00	4.90	12.80	2.55	3.50	4.80
3	2.70	4.20	3.00	5.70	4.10	2.25	1.90	3.80	19.10	2.50	3.50	4.50
4	2.60	3.90	3.10	5.05	3.90	2.20	1.75	3.80	21.00	6.65	3.50	4.60
5	2.60	3.80	2.05	11.95	3.80	2.10	1.70	7.00	21.00	18.70	3.40	6.60
6	2.60	3.80	2.90	17.70	3.65	2.00	2.20	4.30	19.20	22.00	3.45	6.20
7	2.80	3.80	2.75	15.10	3.55	2.00	2.50	4.10	17.10	23.30	3.80	5.40
8	3.00	3.70	2.70	12.10	3.55	1.90	4.75	3.70	11.60	21.75	3.90	4.90
9	2.85	3.55	2.65	9.75	3.40	1.90	2.90	3.40	7.00	16.70	3.55	4.60
10	2.75	3.45	2.65	5.85	3.35	1.85	3.20	3.70	5.40	6.90	3.40	4.30
11	2.70	3.40	2.65	5.45	3.20	1.85	2.90	7.15	5.00	5.65	3.70	4.20
12	6.85	3.30	2.60	5.50	3.20	1.75	2.60	6.70	4.60	5.15	3.70	4.00
13	6.70	3.30	2.60	5.00	3.10	2.40	2.10	5.40	4.40	4.70	3.70	4.00
14	6.85	3.15	2.70	5.10	3.10	3.50	2.20	4.75	3.95	4.55	4.40	4.00
15	5.85	3.10	4.10	5.50	3.05	2.80	3.40	3.85	3.80	4.30	4.15	3.70
16	6.30	3.05	8.15	5.30	2.90	2.50	3.70	3.40	3.70	4.10	4.85	3.60
17	6.50	2.90	9.40	5.00	2.85	2.40	2.75	4.00	3.50	4.00	4.10	3.60
18	5.10	2.90	5.95	4.60	2.80	3.85	2.40	3.20	3.35	8.00	4.40	3.70
19	4.70	3.00	5.35	4.45	2.75	4.00	2.10	4.30	3.20	9.50	6.75	3.70
20	8.90	3.00	4.60	5.60	2.75	5.30	2.00	4.00	3.10	6.30	7.15	4.70
21	10.65	3.00	4.10	5.65	2.60	5.00	1.90	3.35	3.00	5.00	6.00	5.50
22	9.00	2.95	3.85	4.55	2.60	4.45	1.75	5.30	3.00	5.00	5.15	4.90
23	7.30	2.90	3.60	4.20	2.50	3.90	1.90	3.50	5.35	5.85	7.80	5.00
24	7.05	2.80	3.45	10.60	2.55	2.65	1.80	2.95	4.70	4.90	7.10	5.30
25	8.80	2.80	3.55	9.40	3.00	2.40	2.20	2.90	4.40	4.40	5.95	4.55
26	17.10	2.70	3.95	7.15	2.70	2.20	3.20	3.45	4.30	4.25	5.10	4.25
27	16.00	3.00	3.50	6.50	2.50	2.20	3.40	4.65	3.00	4.40	4.80	4.10
28	13.65	3.25	3.30	5.90	2.35	2.30	5.30	3.75	2.90	4.20	4.40	4.00
29	8.20	.....	6.00	5.30	2.30	2.10	5.25	2.80	2.80	4.00	4.60	3.85
30	6.05	.....	11.85	4.90	2.25	2.00	4.20	2.60	2.70	3.90	5.60	3.80
31	5.50	.....	12.50	.....	2.25	.....	5.20	2.65	.....	3.80	.....	3.80

Daily gage height, in feet, of Coosa River at Rome, Georgia, for 1897.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.0	2.8	3.3	7.1	4.1	1.8	1.7	0.8	1.0	0.0	0.5	1.1
2	1.0	9.7	3.2	7.5	4.0	2.3	1.5	.7	.5	.0	.9	1.0
3	1.0	11.5	3.1	8.2	3.5	2.0	1.0	1.2	.3	.0	1.0	1.2
4	1.0	9.6	3.3	9.4	3.3	3.0	0.9	1.0	.5	.1	1.0	2.3
5	1.0	8.2	3.5	14.8	3.0	2.4	2.0	.8	.4	.1	1.0	3.2
6	1.3	5.2	7.6	18.9	3.0	2.0	1.9	.8	.3	.1	.8	3.7
7	1.1	5.0	19.7	17.0	3.0	2.0	1.9	1.9	.3	.1	.8	3.2
8	1.1	4.3	18.9	14.7	2.8	2.0	3.0	2.0	.2	.1	.8	2.2
9	1.0	5.0	15.4	12.1	2.6	2.0	2.1	2.0	.1	.1	.8	1.9
10	1.0	4.4	13.5	9.6	2.6	1.9	1.9	1.6	.0	.1	.7	1.7
11	.9	4.5	12.0	7.2	2.6	1.9	2.5	2.4	.0	.1	.7	1.5
12	.9	7.4	11.5	6.2	3.0	1.9	2.8	1.8	.0	1.1	.7	1.4
13	.9	8.7	18.6	5.8	3.4	1.8	2.0	1.3	.0	1.6	.7	1.3
14	2.8	7.2	21.3	5.0	4.0	1.7	1.6	.8	.0	1.3	.6	2.2
15	6.2	5.5	23.8	6.0	5.0	1.7	1.3	.6	.0	1.0	.6	4.0
16	5.0	4.5	23.4	7.4	4.0	2.0	1.0	.6	.0	.8	.6	3.5
17	3.5	4.0	22.6	7.0	3.3	2.8	5.2	2.1	.0	.7	.6	2.5
18	3.9	3.7	21.4	5.0	2.8	2.3	4.2	3.2	.1	.6	.6	2.2
19	5.0	3.4	19.7	4.5	2.7	2.0	4.8	2.4	.2	.6	.6	1.8
20	3.5	3.0	18.9	4.0	2.6	1.8	8.8	1.4	.2	.6	.6	1.7
21	8.7	4.0	17.7	3.8	2.5	1.6	12.8	1.3	.2	1.5	.6	3.2
22	9.5	3.9	15.3	3.7	2.4	1.5	7.3	1.5	.2	1.3	.5	4.1
23	5.7	5.6	13.7	3.5	2.4	1.5	4.4	1.5	.2	1.0	.5	5.8
24	4.0	11.7	12.9	3.5	2.4	1.4	3.9	1.5	.2	.8	.5	5.3
25	3.5	8.6	9.1	3.5	2.3	1.3	2.6	1.1	.3	.8	.5	3.7
26	3.0	6.7	6.0	3.5	2.2	1.2	2.6	.8	.3	.7	.5	2.8
27	2.5	4.7	5.2	3.4	2.1	1.2	3.8	.5	.4	.7	.5	3.0
28	2.5	3.5	4.8	3.4	2.0	1.0	3.0	.4	.4	.7	.9	2.8
29	2.5	.....	4.5	3.4	2.0	1.1	2.4	.4	.4	.6	1.1	2.3
30	2.3	.....	4.2	3.2	1.9	2.0	1.4	.4	.4	.5	1.1	2.0
31	2.2	.....	4.0	.....	1.9	.....	1.2	.5	.....	.5	.....	2.0

Daily gage height, in feet, of Coosa River at Rome, Georgia, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.8	3.6	1.2	9.0	2.8	1.4	1.2	4.8	2.0	2.0	2.2	4.2
2	1.8	3.1	1.2	6.1	2.6	1.4	1.0	4.4	7.8	2.0	2.2	4.0
3	1.7	2.8	1.2	4.2	2.4	1.4	1.0	3.2	21.7	2.0	2.2	3.8
4	1.7	2.6	1.2	3.6	2.3	1.4	1.0	4.4	24.3	4.9	2.2	3.8
5	1.6	2.4	1.2	9.9	2.2	1.3	1.0	8.0	22.2	22.0	2.0	4.3
6	1.6	2.2	1.2	17.2	2.1	1.3	1.3	5.6	20.0	23.8	2.2	5.0
7	1.3	2.0	1.2	14.5	2.0	1.3	2.0	4.4	17.6	19.0	2.6	4.3
8	1.3	1.8	1.2	10.9	2.0	1.3	2.8	4.4	16.4	18.4	2.4	4.0
9	1.3	1.8	1.2	7.0	2.0	1.3	3.2	3.4	9.7	16.6	2.3	3.7
10	1.3	1.7	1.2	4.1	2.0	1.3	1.7	3.0	5.0	14.0	2.1	3.4
11	1.4	1.5	1.2	4.0	2.0	1.3	2.8	9.9	5.4	5.6	2.0	3.3
12	2.0	1.5	1.2	3.8	1.9	1.2	2.0	7.2	4.6	4.2	2.0	3.3
13	4.0	1.3	1.2	3.6	1.8	1.4	1.8	4.2	3.8	3.8	2.0	3.2
14	4.0	1.3	1.3	3.5	1.8	1.8	1.6	3.4	3.2	3.7	2.3	3.0
15	3.8	1.3	1.6	3.5	1.7	1.8	3.7	3.0	3.0	3.5	2.3	3.0
16	3.6	1.3	3.7	3.4	1.6	1.7	3.7	2.5	2.9	3.2	2.9	2.8
17	3.6	1.2	7.3	3.0	1.5	1.8	2.2	2.0	2.7	3.1	2.9	2.7
18	3.2	1.2	5.8	3.0	1.5	1.8	1.9	2.2	2.5	6.5	4.0	2.6
19	2.8	1.2	3.7	3.0	1.5	2.2	1.7	2.2	2.3	9.0	5.0	2.6
20	4.4	1.2	3.0	3.6	1.4	3.6	1.6	3.2	2.2	6.0	4.5	2.6
21	6.5	1.2	2.5	3.6	1.4	3.2	1.5	2.8	2.2	4.2	5.0	2.8
22	6.4	1.2	2.5	3.2	1.4	3.0	1.4	3.9	2.3	3.9	4.0	2.9
23	5.0	1.2	2.3	3.0	1.4	2.8	1.3	2.2	2.6	4.0	5.0	3.2
24	4.5	1.2	2.2	7.2	1.4	2.6	1.8	2.2	4.1	3.9	7.0	3.6
25	7.0	1.2	2.1	8.2	1.4	2.0	3.7	1.9	3.1	3.5	4.7	3.0
26	14.0	1.2	2.0	6.0	1.4	1.8	3.8	2.7	3.0	3.3	3.9	2.9
27	14.6	1.2	1.9	4.6	1.4	1.8	2.9	4.0	2.7	3.1	4.5	2.7
28	11.6	1.2	1.8	4.0	1.4	1.8	3.7	4.4	2.5	3.0	4.3	2.6
29	8.6	.....	2.0	3.7	1.4	1.6	4.2	3.4	2.3	2.8	4.3	2.5
30	4.6	.....	8.5	3.2	1.4	1.4	4.1	2.0	2.1	2.6	3.9	2.4
31	3.9	.....	11.4	.....	1.4	.....	4.2	2.3	.....	2.4	.....	2.4

Daily gage height, in feet, of Coosa River at lower gage, Lock No. 4, 3 miles above Riverside, Alabama, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.0	6.3	1.5	9.2	4.5	1.1	0.9	4.8	2.1	1.4	3.0	4.5
2	3.0	4.9	1.5	9.0	4.0	1.0	.8	4.5	1.8	1.4	2.8	4.4
3	2.4	4.2	1.8	8.0	3.6	1.0	.7	4.5	2.0	1.6	2.7	4.3
4	2.1	3.4	1.8	6.2	3.3	1.1	.7	4.5	6.4	2.0	2.6	4.1
5	1.7	3.4	1.7	7.1	3.1	1.1	.4	3.7	10.4	8.1	2.4	4.0
6	1.6	3.1	1.6	10.5	2.8	1.0	.5	4.3	12.0	12.8	2.5	4.3
7	1.5	2.8	1.7	12.1	2.8	.9	.7	6.5	12.7	13.6	2.4	4.6
8	1.5	2.7	1.7	12.3	2.4	.8	.7	6.6	13.0	18.0	2.5	4.8
9	1.4	2.6	1.5	11.7	2.3	.7	1.0	5.0	13.5	17.0	2.9	4.3
10	1.4	2.6	1.5	10.0	2.2	.7	1.6	4.9	12.4	15.0	3.0	4.0
11	1.6	2.5	1.5	8.0	2.2	.6	2.7	4.8	10.0	14.8	2.8	3.6
12	1.9	2.4	1.4	6.0	2.2	.6	2.6	5.7	6.7	13.5	2.6	3.3
13	2.0	2.3	1.4	5.0	2.0	.7	2.1	8.0	5.5	9.4	2.8	3.2
14	2.5	2.3	1.4	4.5	1.9	.9	1.7	7.0	4.6	6.0	3.3	3.1
15	3.6	2.2	1.4	4.2	1.9	.9	2.0	5.3	3.7	4.6	3.3	3.0
16	4.1	2.0	1.7	4.0	1.9	1.0	2.4	4.1	3.1	4.1	3.4	2.8
17	4.2	1.9	2.8	3.9	1.7	1.0	3.4	3.3	2.8	3.7	3.6	2.7
18	4.1	1.8	4.0	3.7	1.5	1.0	3.4	2.8	2.7	4.9	3.5	2.5
19	3.9	1.8	5.7	3.7	1.4	1.3	2.7	2.5	2.4	6.5	3.6	2.6
20	4.1	1.8	5.4	6.2	1.4	1.2	1.9	2.4	2.3	7.6	4.2	5.1
21	4.6	1.8	4.2	6.9	1.4	1.5	1.4	2.4	2.0	7.9	4.8	5.7
22	6.3	1.8	3.4	6.0	1.4	2.1	1.4	2.6	2.0	7.0	5.9	5.5
23	7.0	1.7	3.0	6.2	1.4	2.5	1.0	2.5	2.8	6.0	7.3	5.0
24	7.0	1.7	2.7	6.8	1.3	2.5	1.0	2.5	5.0	5.0	6.8	4.6
25	7.0	1.6	2.4	8.2	1.2	2.0	1.1	2.7	4.8	4.5	6.5	4.3
26	9.5	1.6	2.2	8.9	1.2	1.6	1.2	2.2	3.9	4.4	6.2	4.2
27	11.0	1.6	2.1	8.8	1.2	1.6	2.3	1.8	3.4	4.0	5.4	4.0
28	11.7	1.5	2.1	7.2	1.5	1.6	3.6	1.7	3.2	3.8	4.6	3.7
29	11.6	.....	2.1	5.9	1.1	1.4	3.6	1.7	2.3	3.6	4.4	3.4
30	10.4	.....	3.8	5.0	.9	1.1	3.8	3.8	2.0	3.2	4.4	3.2
31	8.6	.....	5.7	.....	.8	.....	4.9	3.0	.....	3.0	.....	3.1

Daily gage height, in feet, of Coosa River at Riverside, Alabama, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.30	6.00	1.65	6.80	3.90	1.30	1.15	4.25	2.20	2.20	2.60	3.70
2	2.15	5.25	1.70	7.50	3.60	1.25	1.05	4.00	1.80	1.80	2.50	4.00
3	2.10	4.00	1.80	6.80	3.30	1.20	1.00	4.10	1.75	1.70	2.50	3.90
4	2.00	3.25	1.80	5.50	3.05	1.20	.95	4.00	5.80	2.00	2.45	3.70
5	1.90	3.00	1.80	5.80	2.90	1.30	.95	3.30	9.30	6.80	2.40	3.70
6	1.85	2.80	1.75	9.30	2.70	1.25	.90	4.00	10.20	11.20	2.40	3.90
7	1.75	2.75	1.70	10.50	2.55	1.20	.95	5.50	11.00	11.90	2.40	4.00
8	1.70	2.70	1.70	10.80	2.40	1.10	1.00	5.30	11.30	15.80	2.40	4.00
9	1.65	2.60	1.65	10.40	2.30	1.05	1.15	4.50	11.60	14.70	2.45	3.70
10	1.60	2.50	1.65	8.90	2.20	1.05	1.65	4.30	10.80	12.50	2.55	3.30
11	1.60	2.40	1.60	7.50	2.15	1.00	2.15	4.50	8.70	12.00	2.75	3.25
12	1.65	2.30	1.60	6.00	2.10	1.48	2.15	4.70	5.80	11.20	2.75	3.10
13	1.80	2.30	1.70	5.00	2.00	1.10	2.10	6.70	4.75	8.80	2.70	3.00
14	2.00	2.20	1.80	4.40	1.95	1.25	2.15	5.90	4.10	5.50	2.65	2.90
15	3.10	2.10	2.00	4.00	1.90	1.15	2.05	4.70	3.40	4.40	2.70	2.80
16	3.00	2.00	2.25	3.70	1.85	1.00	2.30	3.70	3.00	3.60	2.80	2.65
17	2.80	1.95	3.00	3.50	1.80	1.65	3.10	3.00	2.70	3.00	3.00	2.60
18	2.60	1.90	4.75	4.00	1.75	1.70	3.05	2.75	2.50	3.50	3.15	2.60
19	2.80	1.85	5.50	5.10	1.70	1.65	2.50	2.55	2.25	5.40	3.25	2.70
20	3.00	1.80	4.70	5.80	1.60	1.55	1.90	2.45	2.20	6.40	3.70	2.90
21	4.10	1.80	4.00	5.50	1.70	1.95	1.65	2.40	2.15	6.30	4.20	4.00
22	5.80	1.80	3.25	4.00	1.65	2.10	1.50	2.40	2.20	6.00	5.15	3.80
23	6.05	1.75	3.00	4.50	1.55	2.30	1.35	2.35	2.55	5.80	7.00	3.40
24	6.50	1.75	2.75	5.75	1.50	2.50	1.25	2.30	3.55	5.00	5.90	3.00
25	7.20	1.70	2.30	7.10	1.45	2.05	1.20	2.15	4.30	4.35	5.20	2.75
26	9.00	1.70	2.15	7.80	1.40	1.75	1.40	2.00	3.90	4.00	4.90	2.70
27	10.20	1.70	2.00	7.45	1.55	1.50	2.35	1.80	3.40	3.75	4.60	2.50
28	10.65	1.65	2.00	6.45	1.70	1.60	3.15	2.00	3.15	3.30	4.20	2.40
29	10.45	.....	2.30	5.50	1.60	1.45	3.10	2.50	3.00	3.00	4.00	2.30
30	9.45	.....	3.00	4.75	1.45	1.30	3.40	3.00	2.75	2.75	3.80	2.30
31	7.55	.....	4.50	.....	1.35	.....	4.00	2.60	.....	2.70	.....	2.40

nly gage height, in feet, of Coosa River, at Lock No. 5 (Collins Ferry, Alabama), for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.0	3.6	0.5	5.0	2.4	0.4	0.3	2.5	1.0	0.7	1.4	2.4
2	.9	2.6	.5	5.7	2.0	.3	.1	2.5	.7	.7	1.3	2.4
3	.8	2.0	.5	5.1	1.8	.3	.1	2.3	.8	.6	1.2	2.4
4	.7	1.9	.5	3.8	1.6	.3	.1	2.3	3.1	1.5	1.2	2.3
5	.6	1.6	.6	4.5	1.4	.2	.1	1.9	7.1	5.2	1.2	2.0
6	.6	1.4	.6	7.5	1.3	.2	.1	2.2	8.5	10.3	1.4	2.2
7	.5	1.3	.6	8.6	1.2	.1	.1	3.8	8.9	10.3	1.3	2.4
8	.5	1.2	.6	8.8	1.1	.1	.8	3.5	9.4	14.7	1.2	2.3
9	.5	1.2	.5	8.4	1.0	.1	.4	3.1	9.5	13.7	1.3	2.5
10	.5	1.1	.5	7.2	.9	.1	.6	2.7	8.8	12.7	1.4	2.0
11	.5	1.1	.5	5.3	.9	.1	.8	3.0	7.1	11.0	1.4	1.9
12	.7	1.0	.5	3.5	.9	.1	.4	3.2	4.1	9.9	1.3	1.7
13	.8	1.0	.5	2.8	.8	.8	.8	5.0	3.1	7.0	1.5	1.6
14	.9	.9	.5	2.4	.8	.3	.9	4.3	2.5	4.4	1.7	1.5
15	1.6	.8	.5	2.3	.7	.3	1.0	3.0	1.9	2.6	1.7	1.5
16	2.0	.8	.6	2.0	.7	.3	1.0	2.2	1.5	2.1	1.7	1.4
17	2.1	.7	1.2	1.9	.7	.5	1.5	1.7	1.3	1.9	1.8	1.3
18	2.1	.7	1.8	.8	.6	.6	1.6	1.3	1.2	2.5	1.8	1.3
19	1.9	.6	3.0	1.8	.6	.4	1.2	1.5	1.1	3.6	2.0	1.3
20	2.1	.6	3.0	3.2	.5	.4	.8	1.4	1.0	4.6	2.7	2.5
21	2.7	.6	2.3	4.0	.5	.4	.7	1.3	.9	5.0	2.6	3.3
22	3.5	.7	1.6	3.5	.5	.7	.6	1.2	.9	4.4	3.3	3.2
23	4.0	.7	1.3	2.9	.5	1.0	.3	1.1	1.2	3.6	4.2	2.8
24	4.1	.6	1.1	4.1	.5	1.1	.3	1.0	2.7	2.8	4.3	2.5
25	4.1	.6	1.0	5.0	.5	.8	.3	1.3	2.6	2.5	4.0	2.3
26	6.5	.6	.9	5.6	.5	.6	.5	1.2	2.0	2.1	3.7	2.2
27	7.7	.6	.9	5.3	.4	.4	1.3	1.0	1.6	2.0	3.1	2.1
28	8.4	.5	.8	4.4	.5	.5	1.6	.8	1.1	1.8	2.6	1.8
29	8.2	.....	.8	3.4	.5	.5	1.6	1.1	1.0	1.6	2.4	1.6
30	7.3	.....	1.5	2.9	.4	.4	1.8	1.9	.8	1.5	2.4	1.5
31	5.5	.....	3.3	.....	.4	.....	2.0	1.4	.....	1.4	.....	1.6

ly gage height, in feet, of Coosa River 3 miles above Wetumpka, Alabama, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.0	7.3	1.9	5.1	4.6	0.9	1.4	5.3	2.0	1.9	2.4	4.8
2	2.0	5.9	2.0	6.7	4.1	.9	.9	5.8	2.0	1.6	2.6	4.4
3	1.9	5.0	2.0	7.0	3.7	.9	.6	6.1	1.7	1.4	2.6	5.4
4	1.8	4.3	1.8	7.5	3.5	.9	.5	6.7	1.7	4.8	2.6	5.4
5	1.7	3.5	1.7	8.7	3.2	.9	.7	5.3	1.7	5.8	2.5	4.9
6	1.7	4.3	1.8	9.3	3.0	.8	.9	4.1	3.1	8.4	2.4	4.4
7	1.6	4.0	1.7	12.1	2.7	.8	1.2	4.6	4.7	12.5	2.9	4.0
8	1.5	3.8	1.7	11.3	2.4	.7	1.6	4.8	5.9	12.8	2.9	4.2
9	1.7	3.5	1.6	10.5	2.4	.5	1.9	5.0	7.5	17.5	2.5	4.3
10	1.7	3.0	1.6	9.9	2.2	.5	1.8	5.7	10.1	16.0	3.5	4.7
11	1.8	2.7	1.6	8.1	2.0	.5	1.5	9.8	9.9	13.8	4.6	4.2
12	1.9	2.3	1.4	7.3	2.0	.5	1.4	8.6	8.5	12.2	3.7	3.9
13	2.1	2.2	1.4	6.1	1.8	.5	1.6	7.4	7.6	10.0	3.2	3.7
14	2.3	2.0	1.4	5.0	1.7	.3	1.7	7.8	6.8	8.2	4.0	3.5
15	2.5	2.0	1.3	4.3	1.7	.3	2.5	7.0	4.6	5.5	4.3	3.2
16	1.8	1.8	1.2	3.7	1.7	.8	3.0	6.3	3.8	4.2	4.0	3.0
17	1.8	1.7	1.2	3.6	1.6	.9	1.8	5.2	3.0	1.3	3.9	2.9
18	2.0	1.6	1.4	3.4	1.6	1.0	1.8	4.7	2.6	2.7	4.1	2.9
19	2.4	1.4	1.8	3.7	1.4	1.2	2.1	4.1	2.3	4.0	6.0	3.0
20	2.9	1.4	3.4	3.9	1.4	1.2	2.6	3.3	2.1	5.2	5.0	5.8
21	3.4	1.4	2.9	4.3	1.3	1.5	2.9	2.5	1.9	6.8	4.8	5.9
22	4.8	1.3	2.7	5.7	1.3	1.9	1.4	2.4	1.9	7.0	5.3	5.9
23	5.5	1.3	2.7	5.9	1.3	2.3	1.2	2.4	1.9	6.3	7.3	5.7
24	6.1	1.3	2.4	7.1	1.1	2.5	1.4	2.1	1.8	4.5	7.4	5.2
25	7.5	1.3	2.4	7.9	1.1	2.5	1.4	2.9	3.8	4.7	6.6	4.7
26	8.1	1.2	2.2	8.1	1.0	2.3	2.1	3.2	3.8	4.2	6.0	4.4
27	8.7	1.8	2.0	7.0	.9	2.0	1.7	3.8	3.5	4.1	5.8	4.0
28	9.5	1.8	1.8	6.3	.9	2.0	2.0	2.8	3.0	3.7	5.2	4.0
29	10.0	.....	1.8	5.7	.9	1.8	3.2	2.8	2.5	3.5	5.3	3.7
30	9.0	.....	2.7	5.2	.9	1.5	4.2	2.4	2.3	2.6	5.3	3.5
31	8.5	.....	3.9	.....	.9	.....	4.9	2.4	.....	2.5	.....	3.5

Daily gage height, in feet, of Tallapoosa River at Milstead, Alabama, for 1

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	2.90	2.30	1.90	4.90	2.60	1.10	1.50	3.60	4.30	1.30	2.30
2	1.90	2.20	1.80	3.90	2.30	1.10	1.30	2.90	3.20	1.30	2.20
3	1.60	2.10	1.90	3.10	2.20	1.10	1.20	2.80	2.70	1.40	2.20
4	1.70	2.00	2.40	3.00	2.10	1.10	1.10	11.50	2.70	16.00	2.10
5	1.70	2.00	2.90	17.00	2.00	1.10	1.50	14.00	4.00	22.00	2.10
6	1.60	2.00	2.40	18.80	2.00	1.10	1.30	8.90	4.60	23.50	2.20
7	1.80	2.00	2.50	12.10	1.90	1.00	1.70	10.10	6.00	16.40	2.70
8	1.60	2.00	2.30	7.10	1.90	.90	2.90	8.50	5.60	22.80	4.20
9	1.90	2.00	2.20	5.20	1.80	.90	4.90	7.90	4.50	14.00	2.80
10	1.90	1.90	2.00	4.00	1.60	.90	3.60	5.30	3.50	7.90	3.00
11	1.90	1.90	2.00	3.40	1.70	.80	4.40	17.30	2.90	5.90	7.10
12	2.40	1.90	2.00	3.10	1.70	.90	2.00	22.60	2.60	4.90	5.10
13	2.40	1.90	1.90	3.00	1.70	1.20	1.70	10.10	2.50	3.80	5.00
14	2.00	1.90	1.90	2.90	1.60	1.20	2.70	7.70	2.40	3.40	5.90
15	2.40	1.80	2.70	2.80	1.60	1.10	3.50	6.10	2.20	3.00	5.50
16	2.40	1.80	2.60	2.60	1.60	1.20	5.10	4.20	2.00	2.70	5.40
17	2.40	1.80	2.50	2.40	1.60	2.10	2.40	3.40	1.80	2.60	6.20
18	2.30	1.60	2.60	2.40	1.60	1.80	2.80	2.80	1.70	4.40	6.10
19	2.20	2.20	2.50	2.20	1.50	1.40	3.65	2.60	1.60	5.00	14.40
20	2.20	2.30	2.40	2.40	1.50	1.40	2.30	2.80	1.60	4.40	12.20
21	3.10	2.30	2.20	2.80	1.40	1.40	1.90	2.50	1.50	3.70	10.00
22	3.10	2.10	2.00	2.70	1.40	3.00	1.60	2.30	1.50	3.30	8.00
23	3.00	2.00	1.90	2.80	1.30	2.40	1.60	2.20	1.50	3.10	10.00
24	2.90	2.00	1.90	14.50	1.30	2.20	1.50	2.00	1.60	2.70	8.80
25	2.60	1.90	1.80	11.00	1.20	2.10	1.50	2.10	1.40	2.60	7.90
26	2.90	1.80	1.80	5.90	1.20	1.80	2.50	8.10	2.00	2.50	5.30
27	3.60	1.80	1.80	4.30	1.20	1.50	2.60	10.20	1.80	2.40	4.60
28	3.90	1.80	1.70	3.30	1.20	1.80	4.10	8.40	1.60	2.40	4.10
29	3.10	.....	2.20	2.95	1.20	2.70	2.80	7.00	1.50	2.40	4.90
30	2.65	.....	4.20	2.80	1.20	1.90	2.90	5.20	1.50	2.40	5.40
31	2.40	.....	5.30	.....	1.10	.....	3.80	5.10	.....	2.30	.....

Daily gage height, in feet, of Black Warrior River at Tuscaloosa, Alaba
1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	7.10	21.68	3.67	25.50	11.34	0.23	0.66	2.45	1.20	−0.60	0.90
2	6.28	18.30	3.78	22.40	9.82	.08	.43	1.95	.82	− .70	.70
3	5.52	14.90	4.03	18.50	8.67	.23	.30	2.45	.70	− .80	.60
4	4.96	12.12	4.05	15.31	7.68	.27	.53	2.80	.30	− .90	.40
5	4.41	10.15	3.98	29.82	6.88	.27	.16	2.96	.00	−1.00	.00
6	4.17	9.42	3.90	38.70	6.20	.15	.10	3.90	−.10	− .90	.30
7	4.13	8.90	3.57	38.55	5.59	.02	−.18	3.40	−.30	− .90	.50
8	4.18	8.43	3.33	32.83	5.00	−.10	−.04	3.10	−.20	− .70	.40
9	4.17	7.84	3.12	27.70	4.50	−.29	−.04	3.98	.00	− .30	.40
10	3.97	7.30	3.00	23.04	4.20	−.41	+.10	6.20	.20	+2.00	.50
11	4.00	6.68	2.90	19.50	3.91	−.54	.08	12.20	.40	3.30	.50
12	4.18	6.30	2.83	17.03	3.50	−.62	−.07	14.10	.20	2.60	.40
13	6.70	6.20	2.80	15.01	3.21	−.71	−.10	10.60	.00	2.00	.50
14	9.70	6.08	3.00	12.93	2.98	−.62	−.07	7.30	−.30	1.40	.80
15	11.97	5.86	4.80	11.65	2.58	−.53	−.11	5.00	−.30	1.00	1.10
16	11.71	5.40	8.00	10.78	2.30	−.38	−.07	3.50	−.40	.80	1.30
17	15.00	5.00	15.40	9.60	2.08	−.48	−.14	2.62	−.60	.40	1.50
18	15.53	4.90	14.10	8.63	1.97	−.56	.00	1.91	−.70	.80	1.60
19	14.32	4.83	11.92	8.15	1.64	−.30	1.24	1.50	−.70	.80	1.90
20	24.50	4.84	10.08	27.80	1.43	−.21	1.30	1.46	−.80	1.20	2.20
21	33.54	4.70	8.82	33.11	1.23	.00	1.12	1.12	−.90	3.10	2.50
22	31.42	4.48	7.80	28.45	1.07	.07	.88	1.26	−.50	3.80	4.00
23	28.50	4.30	6.96	23.77	1.00	.18	.47	1.20	−.60	4.10	8.60
24	30.38	4.00	6.30	22.72	.93	.30	1.08	.90	−.70	4.80	11.70
25	30.12	3.83	6.00	24.04	.78	.17	1.95	.50	−.80	4.30	11.60
26	42.50	3.64	5.96	22.62	.57	.06	2.50	1.10	−.90	3.90	9.50
27	43.48	3.56	5.53	19.67	.43	1.30	2.00	1.02	−.90	2.90	7.40
28	39.41	3.72	5.12	17.12	.43	1.10	1.80	.98	−.80	2.30	5.90
29	33.80	.....	5.23	15.05	.52	.46	2.03	1.30	−.80	2.00	5.50
30	28.50	.....	13.40	13.03	.44	.68	2.55	1.52	−.60	1.40	5.30
31	24.90	.....	25.68	.....	.30	.....	2.86	1.56	.....	1.10	.....

List of discharge measurements.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
1898.				*Feet.*	*Sec.-feet.*
Feb. 26	Flint River	Molina, Ga	Max Hall	1.80	458
Apr. 21	do	do	do	2.00	877
May 28	do	do	do	1.25	313
Jan. 21	Chattahoochee River.	Oakdale, Ga	do	1.71	2,165
Feb. 28	do	do	do	.65	1,446
Apr. 5	do	do	do	9.95	12,578
May 16	do	do	do	.85	1,501
May 26	do	do	do	.80	1,459
May 28	do	do	B. M. Hall	1.30	a1,088
June 1	do	do	Max Hall	1.35	a1,137
June 30	do	do	do	.80	a782
July 23	do	do	do	2.45	a2,[illegible]92
Aug. 20	do	do	do	4.90	a4,157
Sept. 5	do	do	do	20.10	a24,414
Nov. 19	do	do	do	4.77	a4,735
Jan. 18	do	West Point, Ga	do	2.45	2,648
Feb. 18	do	do	do	2.43	2,464
Mar. 17	do	do	do	3.03	3,571
Apr. 6	do	do	do	9.20	19,886
Apr. 26	do	do	do	4.52	6,704
May 17	do	do	do	2.15	1,975
June 11	do	do	do	1.40	1,161
July 6	do	do	do	2.27	2,451
Aug. 5	do	do	do	8.82	18,506
Sept. 2	do	do	do	7.55	15,067
Sept. 3	do	do	do	11.25	25,202
Oct. 5	do	do	B. M. Hall	13.90	37,579
Oct. 29	do	do	do	3.38	4,409
Nov. 29	do	do	do	4.00	5,394
Jan. 13	Etowah River	Canton, Ga	Max Hall	.60	761
Mar. 5	do	do	do	.33	621
Mar. 29	do	do	B. M. Hall	5.60	5,124
May 20	do	do	do	.60	627
June 4	do	do	Max Hall	.22	495
July 19	do	do	B. M. Hall	.25	413
Aug. 30	do	do	do	.65	1,002
Sept. 6	do	do	do	3.25	3,190
Sept. 7	do	do	do	2.00	2,104
Nov. 18	do	do	do	.90	1,223
Dec. 10	do	do	do	.70	1,064
Jan. 16	Coosawattee River	Carters, Ga	Olin P. Hall	5.70	3,052
Mar. 18	do	do	do	1.80	697
Mar. 30	do	do	do	5.87	3,079
Do	do	do	do	5.35	2,782
May 28	do	do	do	1.36	495
June 25	do	do	do	1.12	385
July 28	do	do	do	2.55	1,019
Aug. 25	do	do	Max Hall	1.77	686
Oct. 5	do	do	Olin P. Hall	12.10	4,909
Nov. 22	do	do	do	4.05	2,006
May 21	Oostanaula River	Resaca, Ga	do	2.65	1,100
July 29	do	do	do	5.41	2,567
Aug. 20	do	do	Max Hall	3.79	1,811
Aug. 27	do	do	do	4.65	2,397
1896.					
Sept. 29	Coosa River	Rome, Ga	do	.20	1,209
1897.					
May 7	do	do	do	2.75	4,646
Oct. 5	do	do	do	—.15	990
1898.					
May 11	do	do	do	1.90	2,946
Sept. 17	do	do	B. M. Hall	2.60	3,913
Oct. 11	do	do	J. C. Conn	5.05	8,324
Oct. 22	do	do	B. M. Hall	4.10	6,489
Nov. 30	do	do	J. C. Conn	3.90	6,039
Jan. 27	do	Riverside, Ala	Max Hall	10.00	30,359
Mar. 9	do	do	do	1.60	3,538
May 3	do	do	do	3.22	7,758
May 25	do	do	B. M. Hall	1.39	3,172
Aug. 3	do	do	Max Hall	3.92	9,524
Sept. 7	do	do	do	11.05	37,811
Oct. 19	do	do	J. C. Conn	6.80	14,484
Nov. 22	do	do	B. M. Hall	5.85	16,384
Jan. 19	Tallapoosa River	Milstead, Ala	Max Hall	2.13	1,889
Feb. 19	do	do	do	2.20	2,045
Mar. 18	do	do	do	2.56	2,646
Apr. 26	do	do	do	5.83	6,648
May 17	do	do	do	1.55	1,059
June 22	do	do	do	3.05	3,421
July 7	do	do	do	1.62	1,262
Aug. 5	do	do	do	13.67	15,295
Sept. 3	do	do	do	2.76	3,010
Nov. 29	do	do	B. M. Hall	5.16	5,477

a 1 mile below Oakdale, at Mason and Turner's ferry.

Rating tables.

Molina.		Oakdale. *a*		Oakdale. *b*		West Point.		Canton. *c*		Canton. *d*	
Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1.0	275	−0.4	820	0.7	730	1.2	1,000	0.0	270	0.0	657
1.1	285	− .2	920	0.8	780	1.6	1,380	.2	380	.2	788
1.2	301	.0	1,020	0.9	840	2.0	1,840	.4	560	.4	922
1.3	324	.2	1,130	1.0	900	2.4	2,380	.6	742	.6	1,059
1.4	354	.4	1,240	1.5	1,215	2.8	3,000	.8	924	.8	1,200
1.5	390	.6	1,350	2.0	1,560	3.2	3,700	1.0	1,106	1.0	1,347
1.6	436	.8	1,470	3.0	2,300	3.6	4,480	1.2	1,288	1.2	1,498
1.7	496	1.0	1,590	4.0	3,250	4.0	5,370	1.4	1,470	1.4	1,655
1.8	566	1.5	1,920	5.0	4,400	4.4	6,400	1.6	1,652	1.6	1,818
1.9	646	2.0	2,270	6.0	5,700	4.8	7,490	1.8	1,834	1.8	1,984
2.0	736	2.5	2,650	7.0	7,000	5.2	8,592	2.0	2,016	2.0	2,150
2.2	980	3.0	3,070	8.0	8,300	5.6	9,696	2.2	2,198	2.2	2,316
2.4	1,305	3.5	3,530	9.0	9,600	6.0	10,800	2.4	2,380	2.4	2,483
2.6	1,645	4.0	4,030	10.0	10,900	6.4	11,904	2.6	2,562	2.6	2,648
2.8	1,985	4.5	4,580	11.0	12,200	6.8	13,008	2.8	2,744	2.8	2,814
3.0	2,325	5.0	5,160	12.0	13,500	7.2	14,112	3.0	2,926	3.0	2,980
3.2	2,665	5.5	5,850	13.0	14,800	7.6	15,240	3.5	3,375	3.5	3,395
3.4	3,005	6.0	6,600	14.0	16,100	8.0	16,400	4.0	3,800	4.0	3,810
3.6	3,350	6.5	7,350	15.0	17,400	8.5	17,850	4.5	4,220	4.5	4,225
3.8	3,690	7.0	8,100	16.0	18,700	9.0	19,300	5.0	4,640	5.0	4,640
4.0	4,030	7.5	8,850	17.0	20,000	9.5	20,750	5.5	5,055	5.5	5,055
4.2	4,370	8.0	9,600	18.0	21,300	10.0	22,200	6.0	5,470	6.0	5,470
4.4	4,710	8.5	10,350	19.0	22,600	10.5	23,650	6.5	5,885	6.5	5,885
4.6	5,050	9.0	11,100	20.0	23,900	11.0	25,100	7.0	6,300	7.0	6,300
4.8	5,390	9.5	11,850	22.0	26,500	11.5	26,590	7.5	6,715	7.5	6,715
5.0	5,730	10.0	12,600	24.0	29,100	12.0	28,800	8.0	7,130	8.0	7,130
.....	.....	10.5	13,350	26.0	31,700	12.5	31,110	8.5	7,545	8.5	7,545
.....	.....	11.0	14,100	28.0	34,300	13.0	33,410	9.0	7,960	9.0	7,960
.....	.....	.....	.....	.....	.....	13.5	35,710	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	14.0	38,030	.....	.....	.....	.....

a Applicable from January 1 to June 30, 1898. Gage heights refer to upper gage.
b Applicable from July 1 to December 31, 1898. Gage heights refer to lower gage.
c Applicable from October 11, 1897, to July 23, 1898.
d Applicable from July 24, 1898, to December 31, 1898.

Carters.		Resaca.		Rome.		Riverside.		Milstead.		Tuscaloosa.	
Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1.0	355	1.0	350	0.0	1,070	1.0	2,320	0.8	540	−2.0	88
1.5	541	1.2	408	.5	1,440	1.5	3,340	1.0	770	−1.0	130
2.0	771	1.4	475	1.0	1,900	2.0	4,400	1.2	1,000	.0	280
2.5	1,031	1.6	552	1.5	2,450	2.5	5,540	1.4	1,230	1.0	600
3.0	1,320	1.8	637	2.0	3,080	3.0	6,800	1.6	1,460	2.0	1,000
3.5	1,625	2.0	727	2.5	3,760	3.5	8,260	1.8	1,690	3.0	1,470
4.0	1,970	2.2	823	3.0	4,540	4.0	9,900	2.0	1,920	4.0	2,000
4.5	2,350	2.4	924	3.5	5,340	4.5	11,615	2.4	2,380	5.0	2,555
5.0	2,660	2.6	1,030	4.0	6,300	5.0	13,330	2.8	2,840	6.0	3,110
5.5	2,915	2.8	1,140	4.5	7,275	5.5	15,045	3.2	3,300	8.0	4,220
6.0	3,125	3.0	1,250	5.0	8,250	6.0	16,760	3.6	3,760	10.0	5,330
6.5	3,300	3.2	1,365	5.5	9,225	6.5	18,475	4.0	4,220	12.0	6,440
7.0	3,430	3.4	1,485	6.0	10,200	7.0	20,190	4.5	4,795	14.0	7,550
7.5	3,575	3.6	1,615	6.5	11,175	7.5	21,905	5.0	5,370	16.0	8,660
8.0	3,720	3.8	1,745	7.0	12,150	8.0	23,620	5.5	5,945	18.0	9,770
8.5	3,865	4.0	1,875	7.5	13,125	8.5	25,335	6.0	6,520	20.0	10,880
9.0	4,010	4.2	2,005	8.0	14,100	9.0	27,050	6.5	7,095	22.0	12,500
9.5	4,155	4.4	2,135	9.0	16,050	9.5	28,965	7.0	7,670	24.0	14,700
10.0	4,300	4.6	2,275	10.0	18,000	10.0	31,200	7.5	8,245	26.0	17,600
11.0	4,590	4.8	2,420	11.0	19,950	10.5	34,062	8.0	8,820	28.0	21,500
12.0	4,880	5.0	2,585	12.0	21,900	11.0	37,600	8.5	9,395	30.0	26,500
13.0	5,170	5.2	2,765	13.0	23,850	11.5	41,200	9.0	9,970	32.0	31,700
14.0	5,460	5.4	2,955	14.0	25,800	12.0	44,800	9.5	10,545	34.0	38,000
15.0	5,750	5.6	3,140	15.0	27,750	12.5	48,400	10.0	11,120	36.0	45,000
16.0	6,040	5.8	3,335	16.0	29,700	13.0	52,000	11.0	12,270	38.0	53,000
17.0	6,330	6.0	3,525	17.0	31,650	13.5	55,600	12.0	13,420	40.0	61,000
18.0	6,620	6.2	3,715	18.0	33,600	14.0	59,200	13.0	14,570	45.0	81,000
19.0	6,910	6.4	3,910	20.0	37,500	14.5	62,800	14.0	15,720	50.0	101,000
20.0	7,200	6.6	4,110	22.0	41,400	15.0	66,400	15.0	16,870	55.0	121,000
22.0	*7,780*	*6.8*	*4,330*	24.0	45,300	15.5	70,000	.....	.....	.....	.....

OHIO RIVER DRAINAGE.

DESCRIPTION OF RIVER STATIONS.

dsville station on Youghiogheny River.—This station at ville, Garrett County, Maryland, was established August 17, y E. G. Paul. The observer is J. H. Cuppet, a merchant ; within a short distance of the gage. The height of water is d by means of a wire attached to the floor timber on the lower the highway iron bridge connecting the east and west portions illage. This wire is 20 feet long from zero to the extreme end eight. The scaleboard is 14 feet long, graduated to tenths of The stream channel is straight for several hundred feet above ow the bridge, and it has a solid bottom with high banks on t-hand side.

rd station on New River.—This is located on the New River y) Bridge, close by Radford Station, on the Norfolk and West- lway. It was established August 1, 1898, by D. C. Hum- The observer of river heights is A. J. Killinger, Radford, . The gage used was erected by the United States Weather and consists of a vertical board, graduated to tenths of a foot, l to the iron framework connecting the pair of iron concrete s which form the first pier from the right bank, close to the f the two cylinders. The bench mark is the bottom of the orizontal brace, connecting the two cylinders; the elevation he zero of the gage is 3.88 feet. The discharge measurements de from the lower edge of the bridge, and the initial point for gs is the right bank of the river, 40 feet from the first pier. nnel is remarkably uniform and nearly straight for about half bove and below the station. The bottom is of solid rock and and is smooth and regular. On the left bank there is a very bottom, and then a steep rocky bluff; on the right bank the which is overflowed in extreme high water, is about 100 yards t all water must go under the bridge, which is about 85 feet w water.

son station on Greenbrier River.—Described on page 58 of No. 15; results for 1897 given on pages 253 and 254 of the nth Annual Report, Part IV.

te station on New River.—Described on page 59 of Paper No. lts for the year 1897 given on pages 255–266, of the Nine- Annual Report, Part IV.

ille station on French Broad River.—Described on page 60 r No. 15; results for 1897 given on pages 257–259 of the Nine- Annual Report, Part IV.

m station on Tuckaseegee River.—Described on page 61 of 5.

m station on Little Tennessee River.—Described on page 62 r No. 15.

Murphy station on Hiwassee River.—Described on page 63 of Paper No. 15; results for 1897 given on page 259 of the Nineteenth Annual Report, Part IV.

Blueridge station on Toccoa River.—This station, at Morganton Bridge, about 4 miles east of the town of Blue Ridge, was established on November 25, 1898, and J. L. Seabolt, mail carrier from Blue ridge to Morganton, Georgia, was employed as observer. He has since died, and his son, H. M. Seabolt, who is now the mail carrier, has been employed in his stead. He crosses the bridge twice every day except Sunday. No readings are had on this day, but figures have been interpolated in the list. The gage is a 14-foot rod in two 7-foot sections, nailed to a tree on the right bank just below the bridge. It is graduated to feet and tenths, and is set to conform to bench marks which were established October 15, 1896, and August 26, 1898. The measurement in 1896 was made at the railroad bridge, about 3 miles below, but is referred to the present gage by comparison of bench marks at the two bridges on August 26, 1898. The bench mark at Morganton Bridge is on the top of the bridge floor on the downstream side, 5 feet from the initial point, and is 18 feet above zero of gage. Morganton Bridge is a wooden, queen-bolt open bridge in three spans with a total length between abutments of 153 feet. The width of the river, including two piers, at ordinary stage, is 143 feet between the banks, the three channels being 50, 38, and 33 feet, respectively.

Chattanooga station on Tennessee River.—Described on page 64 of Paper No. 15; results for 1897 given on pages 260 to 262 of the Nineteenth Annual Report, Part IV.

Columbus station on Olentangy River.—This station, established on November 22, 1898, by H. A. Pressey, Prof. C. N. Brown, and B. H. Flynn is located at the Fifth Avenue Bridge, in Columbus, Ohio. The gagings are made from the downstream side of the bridge, the initial point being on the left bank. The gage is a wooden post graduated to feet and tenths, driven in the bed of the stream near the bridge. The gage rod is referred to a scale cut in the face of the left abutment, from which the high-water readings can be taken directly. The bed is rocky and the banks high and never overflowed. This is the only available section at Columbus on this river at which the banks are not overflowed at high water. The observer is Prof. C. N. Brown, University of Ohio, Columbus.

Columbus station on Scioto River.—This station, established on November 22, 1898, by H. A. Pressey, Prof. C. N. Brown, and B. H. Flynn is located at the Grand View Avenue Bridge, in Columbus, Ohio. The wire gage is on the upstream side of the bridge and is referred to a scale cut in the face of the left abutment, from which high-water reading can be taken directly. The bed is rocky and the banks seldom overflow. The observer is A. T. Scurman, Columbus, Ohio.

TABLES OF DAILY GAGE HEIGHT.

Daily gage height, in feet, of Youghiogheny River at Friendsville, Maryland, for 1898.

Day.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	4.20	4.00	4.90	4.90	17	4.90	4.00	4.20	5.20	5.20
2	.....	4.10	4.00	4.90	4.90	18	4.80	4.00	4.40	5.20	5.10
3	.....	4.10	4.00	4.80	4.80	19	4.70	4.00	4.40	5.20	5.10
4	.....	4.10	4.00	4.70	4.70	20	5.90	4.00	4.90	5.70	6.10
5	.....	4.10	4.00	4.70	4.70	21	5.20	4.00	4.70	5.60	7.50
6	.....	4.30	4.10	4.80	4.70	22	4.90	4.00	7.90	5.40	7.60
7	.....	4.40	4.20	4.70	4.70	23	4.70	4.00	7.00	5.40	7.70
8	.....	4.50	4.20	4.90	4.70	24	4.60	4.40	6.10	5.20	7.10
9	.....	4.40	4.20	5.10	4.70	25	4.60	4.30	5.60	5.10	6.50
10	.....	4.40	4.10	5.10	4.80	26	4.50	4.30	5.60	5.00	5.60
11	.....	4.10	4.10	6.30	4.90	27	4.50	4.20	5.50	4.80	5.60
12	.....	4.00	4.10	5.90	5.10	28	4.40	4.00	5.30	4.90	5.60
13	.....	4.00	4.10	5.70	5.10	29	4.30	4.00	5.10	4.80	5.40
14	.....	4.00	4.20	5.50	5.10	30	4.20	4.00	5.00	4.80	5.30
15	.....	4.00	4.20	5.40	5.20	31	4.20	.....	5.00	.....	5.20
16	.....	4.00	4.30	5.30	5.20						

Daily gage height, in feet, of New River at Radford, Virginia, for 1898.

Day.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	Aug.	Sept.	Oct.	Nov.	Dec.
1	0.90	0.60	0.50	1.00	0.80	17	0.50	0.50	0.80	0.90	0.90
2	.50	.50	.60	.90	.70	18	.60	.40	.80	1.00	.80
3	.40	.50	.70	1.00	.90	19	.50	.40	6.60	1.20	1.20
4	.50	2.00	.80	.90	.80	20	.80	.30	2.90	1.20	1.00
5	3.40	3.90	3.90	.80	2.60	21	.80	.20	2.00	1.00	1.20
6	1.30	1.80	3.85	.90	2.00	22	.90	.30	9.90	1.10	1.30
7	1.50	1.00	3.00	.80	1.90	23	.80	6.30	4.00	1.00	1.50
8	1.00	.80	1.80	1.00	1.80	24	.60	5.80	2.90	.90	1.90
9	.90	.70	.90	.70	1.30	25	.50	1.80	2.00	.80	1.30
10	1.00	.60	.80	.60	1.20	26	.80	1.00	1.90	.90	1.20
11	1.40	.50	1.00	.60	1.10	27	.90	.90	1.80	.80	.90
12	1.90	.50	.90	.90	1.10	28	1.00	.80	1.60	.90	.80
13	1.80	.40	.80	.80	.90	29	.90	.70	1.20	.80	.70
14	1.80	.60	.60	.70	.80	30	.80	.60	1.60	.70	.80
15	1.00	.70	.50	.60	.90	31	.60	.....	1.50	.....	.90
16	.70	.60	.60	.50	1.00						

Daily gage height, in feet, of Greenbrier River at Alderson, West Virginia, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.32	2.82	2.62	5.40	2.85	2.63	1.95	2.20	1.85	1.62	2.60	2.67
2	2.35	2.42	2.58	4.50	2.70	2.50	1.87	2.65	1.85	1.62	2.60	2.63
3	2.77	2.27	2.54	4.10	2.60	2.38	1.81	2.25	1.63	1.57	2.55	2.43
4	2.20	2.40	2.52	3.73	2.55	2.30	1.78	2.20	1.75	1.57	2.40	2.37
5	2.12	2.79	2.50	3.48	2.48	2.20	2.00	6.15	1.68	1.58	2.38	3.25
6	2.15	2.42	2.54	3.53	3.03	2.15	2.35	5.35	1.75	1.60	2.34	3.95
7	2.18	2.41	2.55	3.40	8.03	2.07	2.10	5.35	1.80	1.86	2.34	3.35
8	2.17	2.50	2.55	3.30	7.33	2.02	2.06	3.67	2.00	1.78	2.42	3.05
9	2.19	2.40	2.60	3.30	5.20	1.98	1.95	3.10	1.90	1.70	2.37	2.78
10	3.58	2.50	2.65	3.25	4.23	1.95	1.87	3.08	1.85	1.70	2.30	2.72
11	6.95	2.85	2.60	3.95	3.20	1.90	1.82	7.90	1.80	1.70	2.40	3.00
12	4.90	3.15	2.63	7.08	3.45	2.33	1.70	15.50	1.75	1.72	3.88	2.37
13	4.20	3.65	2.70	5.33	3.17	2.13	1.63	5.56	1.70	1.70	3.40	2.50
14	4.00	3.45	2.75	4.65	3.00	2.02	1.73	4.28	1.65	1.70	3.05	2.55
15	3.60	3.22	2.77	4.57	2.85	2.55	1.70	3.55	1.65	1.70	2.90	2.67
16	7.85	3.05	2.68	4.50	2.90	2.45	1.79	3.15	1.63	1.65	2.72	2.48
17	5.45	2.87	2.67	5.00	2.95	2.38	1.88	2.85	1.63	1.65	2.60	2.13
18	4.20	2.70	5.25	4.30	3.34	2.40	1.90	2.65	1.58	1.65	2.68	2.25
19	3.60	2.80	5.93	3.80	3.20	2.36	2.47	2.50	1.58	2.26	4.60	2.25
20	3.25	3.65	5.15	3.40	3.10	2.55	2.35	2.55	1.58	2.58	6.15	2.42
21	3.26	4.05	4.20	3.20	2.95	2.60	2.20	2.65	1.58	2.93	5.15	2.73
22	3.37	4.65	3.67	3.00	2.82	2.45	2.03	2.50	1.60	9.83	4.22	3.45
23	3.67	3.93	3.40	2.90	5.04	2.40	1.94	2.35	1.65	6.60	3.80	5.70
24	4.60	3.45	3.25	2.80	5.50	2.15	2.05	2.20	1.70	4.30	3.92	5.66
25	4.00	3.18	5.32	3.36	4.60	2.03	2.27	2.25	1.80	3.43	3.60	4.40
26	4.00	2.98	5.28	3.40	3.85	1.96	2.05	2.15	1.82	3.03	3.27	3.70
27	3.98	2.83	4.43	3.43	3.38	1.92	2.08	2.05	1.76	3.02	3.08	3.32
28	3.62	2.68	3.85	3.30	3.05	1.93	3.51	2.05	1.73	2.62	2.88	3.05
29	3.30	.....	4.19	3.15	2.90	2.10	3.38	2.00	1.70	2.60	2.68	2.90
30	3.13	.....	7.95	3.00	2.75	2.02	2.80	1.95	1.68	2.50	2.68	2.73
31	2.90	.....	6.40	.....	2.75	.....	2.45	1.90	.....	2.58	.....	2.70

Daily gage height, in feet, of New River at Fayette, West Virginia, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.40	4.00	2.95	15.43	4.10	4.20	1.30	4.50	2.45	2.20	4.25	5.05
2	2.20	3.30	2.80	11.70	3.85	3.50	1.22	4.50	2.20	2.10	4.20	4.50
3	2.20	2.70	2.65	8.90	3.40	3.10	1.15	4.10	1.95	2.05	4.25	4.20
4	2.15	2.00	2.65	8.00	3.00	2.60	1.07	4.20	1.80	1.80	4.30	4.15
5	2.10	1.55	2.65	7.40	2.85	2.10	1.40	9.55	2.10	1.75	2.50	4.05
6	2.25	1.50	2.68	7.30	3.00	2.05	1.30	12.85	8.20	6.18	2.55	7.40
7	2.40	1.55	2.80	6.80	9.45	1.90	1.35	9.65	5.00	8.20	4.05	6.25
8	2.70	1.50	2.85	7.65	14.95	1.50	1.40	7.10	3.95	6.55	3.90	6.35
9	2.80	1.50	2.95	6.10	10.80	1.35	1.65	7.05	3.65	4.20	3.95	5.00
10	3.60	1.40	2.90	6.05	7.40	1.15	1.60	13.05	3.20	3.55	4.10	4.05
11	4.55	3.10	2.75	6.80	6.10	1.15	1.50	19.15	2.20	3.50	4.05	3.30
12	6.40	4.20	2.70	10.85	5.55	1.50	1.45	16.10	2.40	3.35	3.95	3.40
13	6.80	5.40	2.65	9.80	4.95	1.50	1.40	10.85	2.20	3.10	3.80	3.45
14	5.85	4.85	2.60	8.40	4.55	1.40	1.30	9.05	1.95	3.00	3.90	3.45
15	5.60	4.80	2.80	8.35	4.25	1.30	1.25	8.00	1.65	2.65	3.90	3.40
16	7.40	3.70	3.05	10.30	4.30	1.35	1.20	6.80	1.55	2.60	3.55	3.40
17	10.00	3.20	3.60	8.15	4.58	1.48	1.15	5.55	1.30	2.40	3.50	3.35
18	7.05	3.00	4.00	6.80	4.50	2.50	1.00	4.80	1.30	2.30	3.35	3.30
19	6.80	2.85	8.55	6.00	4.45	5.40	3.00	4.35	1.30	2.25	3.45	4.35
20	6.10	3.10	8.30	5.70	4.30	8.10	3.20	4.25	1.20	12.05	5.75	6.50
21	4.25	5.45	6.70	5.30	3.95	6.30	3.45	4.05	1.15	11.70	8.10	8.10
22	5.85	6.15	6.00	5.00	3.80	6.00	2.15	4.00	1.20	14.10	7.40	7.20
23	6.10	5.70	6.80	4.30	11.40	4.80	2.05	3.40	1.20	21.25	5.50	7.45
24	6.70	5.10	7.35	4.50	13.90	3.25	2.00	3.20	8.43	14.40	5.55	9.00
25	8.10	4.40	8.60	4.55	11.25	2.55	2.48	2.95	9.35	9.00	5.60	6.55
26	7.35	3.65	10.15	5.10	9.10	2.20	5.15	2.60	8.10	6.55	6.10	6.10
27	8.90	3.40	10.05	5.15	7.00	1.95	4.80	2.45	7.00	5.10	4.80	5.25
28	8.60	3.10	7.25	5.05	5.95	1.60	4.45	2.20	5.30	4.15	4.65	4.10
29	6.95	.....	10.00	4.60	5.45	1.55	4.60	3.15	4.60	3.40	4.60	4.00
30	5.40	.....	13.90	4.35	5.40	1.40	4.65	3.30	2.70	3.30	4.45	3.65
31	5.05	.....	17.85	.....	4.80	.....	4.60	3.20	.....	3.30	.....	5.10

Daily gage height, in feet, of French Broad River at Asheville, North Carolina, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.25	3.52	2.77	4.60	3.30	2.70	2.55	3.70	3.60	3.45	3.50	3.60
2	3.25	3.47	2.75	4.05	3.30	2.67	2.35	3.90	3.50	3.33	3.60	3.55
3	3.15	3.45	2.73	4.05	3.27	2.63	2.65	4.10	3.45	5.25	3.50	3.30
4	3.03	3.35	2.70	4.10	3.25	2.63	2.63	8.55	6.33	8.10	3.43	3.25
5	2.87	3.15	2.70	4.20	3.17	2.60	2.60	7.23	6.00	7.50	3.40	3.30
6	2.93	3.10	2.70	4.23	3.10	2.60	2.60	6.40	5.75	6.75	3.35	3.35
7	2.90	3.05	2.65	4.10	3.03	2.55	2.55	5.77	5.90	7.03	3.03	3.40
8	2.90	3.00	2.63	3.30	3.03	2.55	2.55	5.60	5.00	6.05	3.25	3.35
9	2.80	3.00	2.63	3.40	3.00	2.55	2.55	5.00	4.65	6.00	3.02	3.25
10	2.80	2.90	2.60	3.40	3.00	2.53	3.40	4.40	4.30	5.60	3.15	3.20
11	2.90	2.85	2.60	3.40	2.90	2.50	2.85	6.60	4.25	5.40	3.01	3.15
12	3.00	2.80	2.60	3.37	4.00	2.50	2.80	7.20	3.95	4.70	3.01	3.13
13	3.00	2.85	2.63	3.25	4.00	2.60	4.95	6.95	3.90	3.80	3.10	3.10
14	2.93	2.77	2.60	3.27	3.40	2.65	7.00	6.50	3.80	3.80	3.50	3.00
15	2.90	2.73	2.60	3.25	3.30	2.70	6.65	6.00	3.75	3.80	3.10	2.97
16	2.85	2.75	2.60	3.25	3.05	2.90	6.50	5.00	3.65	3.60	3.15	2.95
17	2.85	2.75	2.75	3.23	3.00	3.00	6.50	4.40	3.57	3.80	3.20	2.90
18	2.77	3.00	2.73	3.20	2.95	3.35	6.00	4.40	3.55	6.30	3.30	2.93
19	3.20	3.15	2.70	3.17	2.95	4.50	5.00	4.40	3.50	6.20	3.20	3.10
20	3.30	3.10	2.70	3.15	2.93	4.50	3.85	4.37	3.45	6.10	3.20	3.25
21	4.20	3.07	2.85	2.97	2.90	4.00	4.10	4.35	3.40	6.10	3.25	3.30
22	4.30	3.05	2.85	2.95	2.90	3.90	5.30	4.30	3.40	7.00	3.27	4.80
23	4.30	2.95	2.83	3.95	3.10	3.55	5.20	4.23	7.30	6.50	3.23	5.50
24	4.40	2.90	2.80	3.90	3.05	2.70	4.90	4.15	6.60	5.00	3.30	5.00
25	4.50	2.80	2.77	3.90	2.90	2.55	4.50	4.03	5.70	4.10	3.25	4.90
26	5.30	2.80	2.73	4.27	2.80	2.50	4.20	4.00	4.90	4.00	3.25	4.50
27	4.00	2.83	2.71	4.25	2.70	2.60	4.00	3.90	3.85	4.00	3.20	4.00
28	3.75	2.80	2.70	4.20	2.75	3.20	3.80	3.80	3.80	3.35	3.30	5.50
29	3.65	.....	5.00	3.70	2.75	3.15	3.70	3.73	3.70	3.30	3.40	5.20
30	3.60	.....	6.00	3.30	2.75	3.12	3.60	3.70	3.50	3.33	3.53	5.10
31	3.55	.....	5.70	.....	2.73	.....	3.53	3.70	.....	3.30	.....	4.70

age height, in feet, of Tuckaseegee River at Bryson, North Carolina, for 1898.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
..	1.50	1.80	1.50	3.10	2.00	1.50	1.40	2.30	2.00	1.85	2.00	2.20
..	1.20	1.75	1.40	2.80	1.90	1.40	1.35	2.40	3.10	1.70	1.95	2.15
..	1.30	1.75	1.40	2.60	1.85	1.35	1.30	2.50	8.50	1.70	1.90	2.09
..	1.40	1.85	1.40	2.50	1.80	1.35	1.40	7.80	4.50	7.60	1.80	2.70
..	1.40	1.70	1.35	2.80	2.00	1.30	1.50	4.10	6.00	5.70	1.80	2.50
..	1.35	1.60	1.35	2.50	1.90	1.30	1.55	3.50	3.80	4.30	1.95	2.25
..	1.50	1.65	1.35	2.50	1.85	1.30	1.60	2.80	3.60	3.60	1.90	2.20
..	1.40	1.60	1.35	2.40	1.85	1.30	1.60	2.60	3.50	3.20	1.90	2.00
..	1.50	1.60	1.30	2.25	1.80	1.30	1.50	2.50	3.25	2.90	2.15	2.00
..	1.60	1.60	1.30	2.65	1.80	1.30	1.40	2.30	2.70	2.80	2.50	1.90
..	1.60	1.55	1.30	2.40	1.80	1.25	1.30	5.30	2.50	2.80	2.00	1.80
..	2.25	1.65	1.35	2.25	1.80	1.40	1.30	3.50	2.30	2.90	2.00	1.80
..	2.25	1.55	1.60	2.20	1.75	1.40	1.30	3.20	2.10	2.40	2.00	1.75
..	2.00	1.55	1.60	2.40	1.60	1.40	3.50	3.00	2.10	2.30	2.00	1.60
..	1.90	1.45	1.70	2.30	1.60	1.30	2.00	2.90	2.00	2.25	1.90	1.70
..	2.10	1.40	1.65	2.25	2.00	1.50	2.00	2.50	2.00	2.25	2.00	1.70
..	1.90	1.40	1.70	2.15	1.60	1.90	1.70	2.40	2.00	5.30	2.10	1.90
..	1.75	1.50	2.10	2.10	1.60	1.70	1.70	2.50	1.90	3.40	2.50	1.80
..	2.20	1.60	1.90	2.20	2.00	1.70	1.50	2.30	1.90	2.80	2.50	1.80
..	3.50	1.60	1.70	2.10	1.90	1.60	1.40	2.30	1.85	2.80	2.40	2.25
..	2.50	1.55	1.60	2.00	1.60	1.40	1.50	2.20	1.70	2.70	2.20	2.20
..	2.20	1.50	1.50	1.95	1.60	1.30	1.55	2.10	4.30	2.55	2.50	2.00
..	2.60	1.40	1.50	2.10	1.80	1.30	1.60	2.00	3.30	2.45	2.40	1.90
..	2.80	1.45	1.70	2.05	1.80	1.35	1.60	2.10	2.80	2.45	2.25	2.35
..	4.50	1.40	1.50	2.50	1.55	1.40	1.90	2.00	2.30	2.20	2.40	2.85
..	3.80	1.40	1.50	2.40	1.55	1.30	1.90	1.90	2.00	2.30	2.20	2.50
..	2.70	1.40	1.60	2.40	1.50	1.30	2.10	1.90	1.90	2.15	2.00	2.25
..	2.50	1.35	1.70	2.20	1.50	1.40	2.40	1.80	1.90	2.10	2.00	2.90
..	2.20	.....	6.70	2.10	1.50	1.35	2.00	1.75	1.85	2.05	2.40	2.80
..	2.10	.....	5.50	2.00	1.50	1.30	2.00	2.00	1.85	2.10	2.25	2.80
..	2.00	.....	3.80	.....	1.50	.....	2.20	2.20	.....	2.00	.....	2.60

age height, in feet, of Little Tennessee River at Judson, North Carolina, for 1898.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
..	2.83	2.57	2.92	5.78	3.42	2.41	2.71	3.35	5.28	3.53	4.58	3.89
..	2.90	2.90	2.80	5.60	3.63	2.42	2.18	3.42	7.22	3.56	4.52	3.89
..	2.73	2.84	2.90	4.32	3.62	2.42	2.19	4.21	11.93	3.82	4.53	3.88
..	2.75	2.93	2.73	3.38	3.60	2.38	2.17	10.38	9.52	8.71	4.53	3.88
..	2.76	2.56	3.00	5.50	3.68	2.39	2.16	5.72	7.21	13.50	4.59	3.81
..	2.70	2.80	2.98	4.58	3.61	2.30	2.13	4.98	6.82	10.22	4.57	3.80
..	2.80	2.59	2.74	3.96	4.23	2.37	2.20	4.52	5.91	8.28	4.58	3.74
..	2.73	2.56	2.78	3.85	3.56	2.36	2.21	4.31	4.51	6.71	4.51	3.74
..	2.71	2.58	2.37	3.38	3.58	2.36	2.20	4.28	4.28	5.89	4.52	3.71
..	2.70	2.38	2.30	3.40	3.53	2.38	2.15	5.78	3.91	5.82	3.98	3.72
..	2.68	2.30	2.34	3.00	3.98	2.37	2.16	7.91	3.92	4.20	3.98	3.70
..	2.89	2.36	2.36	3.56	3.98	2.39	2.78	8.53	3.81	4.00	3.97	3.69
..	2.73	2.60	2.39	3.58	3.70	2.20	3.00	9.02	3.59	3.52	3.98	3.68
..	2.78	2.74	2.40	3.59	3.69	2.33	3.98	8.93	3.58	3.58	3.91	3.68
..	2.76	2.73	2.98	3.52	3.68	2.30	6.81	5.58	3.58	3.54	3.92	3.67
..	2.79	2.76	2.96	3.90	3.62	2.72	4.20	4.93	3.52	3.48	3.92	3.64
..	2.78	2.80	2.96	3.46	3.67	2.71	3.28	4.92	3.49	3.44	3.90	3.63
..	3.00	3.00	3.48	3.40	3.49	2.78	3.00	4.71	3.44	6.95	3.88	3.60
..	3.56	3.11	3.00	3.49	3.51	2.70	2.78	4.83	3.43	4.53	3.87	3.58
..	3.58	3.23	2.98	3.92	3.56	2.62	2.71	4.38	3.48	4.52	3.89	3.59
..	3.59	3.28	2.90	3.90	3.00	2.63	2.68	4.78	3.49	3.98	3.89	3.59
..	4.42	3.00	2.92	3.58	3.90	2.60	2.41	4.91	3.47	3.91	3.88	3.57
..	4.40	3.00	2.93	3.98	3.72	2.70	3.52	4.58	3.42	3.91	3.86	3.57
..	3.58	2.90	2.90	3.52	3.45	2.71	3.21	4.53	3.48	3.84	3.86	4.98
..	3.59	2.29	2.97	3.54	3.42	2.74	3.00	4.51	3.47	3.98	3.84	3.59
..	3.48	2.70	2.97	3.50	3.44	2.70	3.21	4.51	3.46	4.41	3.83	3.57
..	5.58	2.78	2.56	3.28	3.37	2.73	3.58	4.52	3.44	4.52	3.85	3.58
..	5.20	2.78	3.04	3.29	3.33	2.70	3.28	4.53	3.45	4.57	3.88	3.56
..	3.39	.....	8.30	3.24	3.30	2.78	3.29	4.38	3.48	4.61	3.89	3.52
..	3.86	.....	7.79	3.40	2.27	2.79	3.22	4.38	3.52	4.52	3.88	3.53
..	2.94	.....	6.39	.....	2.30	.....	3.30	4.59	.....	4.58	.....	3.50

Daily gage height, in feet, of Hiwassee River at Murphy, North Carolina, for

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	D
1	5.30	5.60	5.22	7.00	5.80	5.12	4.95	5.82	5.40	5.60	5.85	6.
2	5.20	5.45	5.20	6.50	5.80	5.12	4.95	5.60	12.05	5.60	5.85	5.
3	5.10	5.62	5.32	6.21	5.70	5.10	4.90	5.82	13.97	5.50	5.80	5.
4	5.30	5.50	5.30	6.10	5.65	5.10	4.90	9.80	10.10	14.40	5.80	5.
5	5.25	5.50	5.21	8.75	5.65	5.10	5.50	9.35	9.75	11.60	5.80	6.
6	5.30	5.42	5.20	7.00	5.51	5.20	5.20	6.75	7.50	8.30	6.10	6
7	5.30	5.40	5.20	6.55	5.60	5.10	5.10	6.50	7.10	7.30	5.85	6.
8	5.30	5.40	5.20	6.30	5.60	5.10	5.31	7.02	6.85	7.00	5.80	6.
9	5.20	5.40	5.20	6.11	5.60	5.10	5.10	6.80	6.60	6.70	5.80	5.
10	5.25	5.40	5.20	6.05	5.50	5.10	5.30	8.30	6.60	6.50	5.72	5.
11	5.30	5.40	5.20	6.10	5.50	5.05	5.10	10.00	6.30	6.40	5.90	5.
12	6.00	5.30	5.20	6.00	5.50	5.00	5.00	7.50	6.20	6.32	5.85	5.
13	5.85	5.30	5.20	5.90	5.40	5.00	4.91	7.15	6.12	6.20	5.80	5.
14	5.80	5.30	5.30	5.95	5.40	5.01	5.90	6.81	6.05	6.20	5.90	5.
15	5.60	5.30	5.35	5.95	5.40	5.10	6.12	6.40	6.00	6.05	5.85	5.
16	5.80	5.25	5.32	5.85	5.50	5.15	5.70	6.20	5.90	6.00	5.85	5.
17	5.70	5.25	5.40	5.81	5.40	5.50	5.50	6.20	6.00	6.00	5.85	5.
18	5.60	5.22	5.40	5.80	5.40	5.45	5.30	6.30	5.80	9.20	6.00	5.
19	5.60	5.30	5.40	5.75	5.35	5.20	5.21	6.25	5.70	6.70	6.70	5.
20	5.90	5.25	5.40	5.85	5.30	5.15	5.15	6.10	5.70	6.40	6.40	6.
21	6.10	5.35	5.36	5.70	5.30	5.10	5.01	6.10	5.65	6.23	6.20	5.
22	5.90	5.30	5.35	5.70	5.30	5.10	5.30	5.90	5.70	6.30	6.10	5.
23	6.00	5.30	5.30	5.65	5.35	5.05	5.40	5.75	6.05	6.20	6.50	6.
24	5.78	5.27	5.25	6.20	5.60	5.02	5.60	5.70	5.80	6.10	6.25	6.
25	7.75	5.30	5.40	6.10	5.32	5.05	6.00	5.65	5.70	6.10	6.10	5.
26	7.20	5.22	5.40	5.95	5.25	5.00	5.90	5.80	5.70	6.10	6.10	5.
27	6.50	5.22	5.30	6.20	5.25	5.05	5.60	5.70	5.65	6.05	6.00	5.
28	6.18	5.25	5.30	6.10	5.21	5.01	6.20	5.70	5.60	6.00	6.00	5.
29	6.00	.....	11.10	6.00	5.20	5.00	5.80	5.60	5.60	6.00	6.20	5.
30	5.82	.....	9.40	5.90	5.20	4.95	5.65	5.60	5.60	5.95	6.00	5.
31	5.71	.....	7.70	.....	5.10	.....	6.20	5.60	.....	5.90	.....	5.

Daily gage height, in feet, of Toccoa River at Blueridge, Georgia, for 189

Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	De
1		3.10	9		3.10	17		2.80	25	3.15	3.
2		3.00	10		3.00	18		2.70	26	3.20	2.
3		3.00	11		2.90	19		2.50	27	3.40	2.
4		3.20	12		2.80	20		3.10	28	3.40	2.
5		3.40	13		2.80	21		3.00	29	3.40	2.
6		3.40	14		2.80	22		2.80	30	3.40	2.
7		3.10	15		2.80	23		2.40	31		3.
8		3.00	16		2.80	24		3.10			

Daily gage height, in feet, of Tennessee River at Chattanooga, Tennessee, for

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	D
1	3.45	7.55	3.30	17.45	6.40	3.35	2.45	8.15	3.55	3.55	4.60	5.
2	3.25	6.70	3.15	17.80	5.80	3.30	2.35	7.55	3.95	3.30	4.30	5.
3	3.05	6.15	3.00	15.00	5.40	3.30	2.25	6.45	9.15	3.20	4.25	4.
4	2.90	5.40	2.95	11.45	5.05	3.30	2.05	5.35	18.50	3.90	4.05	5.
5	2.75	5.00	3.30	10.35	4.70	2.85	2.35	6.25	25.00	8.90	3.90	5.
6	2.65	4.55	3.45	12.15	4.45	2.55	2.10	11.85	22.15	16.90	3.90	5.
7	2.70	4.45	3.50	11.60	4.35	2.35	2.10	14.65	15.70	16.50	4.25	5.
8	2.80	4.35	3.40	10.30	4.10	2.20	2.15	12.55	11.25	10.75	4.45	5.
9	3.05	4.30	3.25	9.30	4.20	2.05	2.60	10.15	9.50	8.80	4.50	5.
10	3.25	4.15	3.05	8.30	4.15	1.95	3.05	8.50	8.60	8.40	4.45	5.
11	3.25	4.00	2.90	8.60	4.45	1.80	3.50	9.05	7.45	7.55	4.65	5.
12	5.50	3.90	2.85	9.50	4.65	1.95	3.40	12.30	6.45	6.55	5.05	4.
13	13.20	3.80	2.80	9.40	4.40	1.80	3.20	14.85	5.70	6.00	5.30	4.
14	14.40	3.80	2.85	9.00	4.15	1.75	2.80	15.85	5.20	5.70	4.95	4.
15	12.25	3.80	3.15	9.05	3.95	1.65	2.85	14.95	4.80	5.35	4.55	4.
16	12.20	3.70	5.10	9.15	3.90	1.75	3.50	11.60	4.45	4.90	4.40	3.
17	12.35	3.55	5.05	8.60	3.80	2.00	4.55	8.90	4.25	4.70	4.55	3.
18	10.00	3.50	5.20	8.20	3.70	2.35	5.35	7.10	3.95	5.25	4.75	3.
19	9.20	3.30	5.50	8.00	3.70	3.50	4.60	6.40	3.75	6.70	4.95	3.
20	11.70	3.30	6.10	7.95	3.65	4.05	4.15	6.05	3.55	7.75	5.30	5.
21	13.80	3.20	5.70	7.40	3.60	5.35	4.00	5.95	3.45	9.30	5.85	5.
22	13.40	3.25	5.45	7.05	3.60	5.55	3.30	5.65	3.55	8.80	6.05	6.
23	12.55	3.40	5.15	6.60	3.50	5.05	3.30	5.40	5.00	7.65	6.55	5.
24	12.35	3.50	4.65	6.85	3.40	4.55	3.40	4.75	5.05	7.25	6.85	5.
25	12.35	3.60	4.30	6.65	3.45	3.70	3.55	4.30	6.40	7.20	6.55	5.
26	16.05	3.80	4.15	6.60	3.70	3.40	3.55	4.05	7.20	7.60	6.10	5.
27	18.20	3.50	4.45	6.45	4.95	2.90	4.55	4.00	6.15	6.90	5.65	5.
28	16.70	3.35	4.45	7.10	5.60	2.80	5.55	4.10	5.00	6.20	5.15	5.
29	14.15	.....	4.65	7.05	4.90	2.80	5.35	4.30	4.30	5.65	4.80	5.
30	11.20	.....	5.55	6.75	4.20	2.55	5.90	4.10	3.85	5.15	4.95	4.
31	8.95	.....	13.25	.....	3.70	.....	7.90	3.85	.....	4.85	.....	4.

Daily gage height, in feet, of Olentangy River at Columbus, Ohio, for 1898.

Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.
1		1.30	9		1.56	17		1.20	25	1.34	2.45
2		1.25	10		1.80	18		1.17	26	1.31	2.10
3		1.20	11		1.75	19		1.18	27	1.32	1.88
4		1.28	12		1.40	20		2.38	28	1.25	1.70
5		1.62	13		1.50	21		6.20	29	1.29	1.65
6		1.75	14		1.55	22		5.20	30	1.25	1.73
7		1.80	15		1.41	23	1.43	4.50	31		2.40
8		1.70	16		1.40	24	1.41	3.00			

Daily gage height, in feet, of Scioto River at Columbus, Ohio, for 1898.

Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.
1		9.70	9		9.75	17		9.30	25	9.90	13.65
2		9.65	10		9.75	18		9.25	26	9.80	12.65
3		9.70	11		10.00	19		9.45	27	9.85	12.10
4		9.75	12		9.45	20		11.75	28	9.65	11.30
5		9.90	13		9.40	21		15.10	29	9.75	11.05
6		9.90	14		9.55	22	10.20	16.65	30	9.80	11.15
7		9.80	15		9.20	23	10.05	15.65	31		11.75
8		9.95	16		9.25	24	9.95	14.70			

List of discharge measurements.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
1898.				*Feet.*	*Sec.-feet.*
May 12	Youghiogheny River.	Friendsville, Md	E. G. Paul	4.90	571
Aug. 17	do	do	do	4.90	581
July 21	New River	Radford, Va	D. C. Humphreys	0.20	1,812
July 29	do	do	do	1.26	3,814
June 20	Greenbrier River	Alderson, W. Va	do	2.02	403
Aug. 3	do	do	do	2.20	665
Aug. 5	do	do	do	4.43	5,124
Dec. 22	do	do	do	3.45	2,817
June 25	New River	Fayette, W. Va	do	2.60	3,492
Aug. 5	do	do	do	9.15	19,027
Do.	do	do	do	10.06	21,140
Aug. 6	do	do	do	13.02	31,533
Do.	do	do	do	12.95	a 32,128
Dec. 22	do	do	do	5.94	10,902
Jan. 18	French Broad River.	Asheville, N. C	E. W. Myers	2.75	918
Sept. 9	do	do	do	4.45	3,332
Jan. 19	Tuckasegee River	Bryson, N. C	do	2.20	2,175
Jan. 20	do	do	do	3.30	3,695
Sept. 3	do	do	do	6.93	18,959
Sept. 4	do	do	do	3.93	6,059
Sept. 5	do	do	do	4.50	9,086
Do.	do	do	do	5.00	11,777
Sept. 6	Tennessee River	Judson, N. C	do	7.30	9,821
Jan. 21	Hiwassee River	Murphy, N. C	do	6.05	1,170
Sept. 8	do	do	do	6.80	1,620
1896.					
Oct. 15	Toccoa River	Blueridge, Ga	B. M. Hall	2.00	148
1898.					
Aug. 26	do	do	do	2.95	624
Nov. 25	do	do	do	3.15	797
May 10	Tennessee River	Chattanooga, Tenn	Max Hall	4.14	22,066
July 29	do	do	do	5.30	29,693
Aug. 19	do	do	do	6.37	36,671
Oct. 6	do	do	J. C. Conn	17.60	120,359
Oct. 28	do	do	do	6.00	35,953
Nov. 29	do	do	do	4.75	29,569
Do.	do	do	do	4.70	31,340
Nov. 30	Olentangy River	Columbus, Ohio	C. N. Brown	1.20	77

a Approximate.

List of miscellaneous discharge measurements, 1898.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Di char
				Feet.	*Sec.-*
Nov. 15	Youghiogheny River.	Connellsville, Pa	E. G. Paul		1,
Nov. 16	do	Confluence, Pa	do		1,
Do.	Cassellman River	do	do		
Do.	Laurel Hill Creek	do	do		
July 20	Tinker Creek	Roanoke, Va	D. C. Humphreys	0.95	
July 22	North Fork Holston River.	Saltville, Va	do		
July 23	Middle Fork Holston River.	Osceola, Va	do	.30	
Do.	South Fork Holston River.	Drowning Ford, near Abingdon, Va.	do		
July 25	Clinch River	Speers Ferry, Va	do	.40	
Aug. 26	Toccoa River	Near Mineral Bluff, Ga.	B. M. Hall		

Rating tables.

Asheville.		Bryson.		Judson.		Murphy.		Blueridge.		Chattan
Gage height.	Dis-charge.	Gage height.	Dis-charge.	Gage height.	Dis-charge.	Gage height.	Dis-charge.	Gage height.	Dis-charge.	Gage height.
Feet.	*Sec.-ft*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*
2.0	620	1.0	168	2.0	225	4.6	225	2.00	148	0.5
2.1	633	1.2	400	2.2	300	4.7	250	2.05	154	1.0
2.2	645	1.4	670	2.4	445	4.8	280	2.10	160	1.5
2.3	665	1.6	950	2.6	610	4.9	315	2.15	169	2.0
2.4	685	1.8	1,250	2.8	805	5.0	350	2.20	178	2.5
2.5	715	2.0	1,550	3.0	1,060	5.1	400	2.25	191	3.0
2.6	745	2.2	1,870	3.2	1,360	5.2	450	2.30	204	3.5
2.7	782	2.4	2,200	3.4	1,670	5.3	510	2.35	220	4.0
2.8	820	2.6	2,550	3.6	1,990	5.4	570	2.40	236	4.5
2.9	875	2.8	2,900	3.8	2,320	5.5	640	2.45	256	5.0
3.0	930	3.0	3,250	4.0	2,650	5.6	720	2.50	277	5.5
3.1	1,030	3.2	3,600	4.2	3,020	5.7	820	2.55	302	6.0
3.2	1,130	3.4	4,050	4.4	3,390	5.8	920	2.60	327	6.5
3.3	1,230	3.6	4,800	4.6	3,770	5.9	1,020	2.65	363	7.0
3.4	1,330	3.8	5,550	4.8	4,160	6.0	1,120	2.70	400	7.5
3.5	1,430	4.0	6,350	5.0	4,550	6.2	1,320	2.75	445	8.0
3.6	1,530	4.2	7,150	5.5	5,600	6.4	1,520	2.80	490	9.0
3.7	1,630	4.4	8,000	6.0	6,750	6.6	1,720	2.85	535	10.0
3.8	1,730	4.6	8,850	6.5	7,975	6.8	1,920	2.90	580	11.0
3.9	1,830	4.8	9,700	7.0	9,300	7.0	2,120	2.95	624	12.0
4.0	1,930	5.0	10,550	7.5	10,720	7.2	2,320	3.00	670	13.0
		5.2	11,400	8.0	12,275	7.4	2,520	3.05	715	14.0
		5.4	12,250	8.5	14,085	7.6	2,720	3.10	760	15.0
		5.6	13,100	9.0	16,100	7.8	2,920	3.15	797	16.0
		5.8	13,950	9.5	18,275	8.0	3,020	3.20	850	17.0
		6.0	14,800	10.0	20,600	8.5	3,570	3.25	895	18.0
		6.5	16,925	10.5	23,100	9.0	4,120	3.30	940	19.0
		7.0	19,050	11.0	25,600	9.5	4,670	3.35	985	20.0
		7.5	21,300	11.5	28,100	10.0	5,220	3.40	1,030	22.0
		8.0	23,550	12.0	30,600			3.45	1,075	24.0

GREAT LAKES DRAINAGE.

DESCRIPTION OF RIVER STATIONS.

Waterville station on Maumee River.—This station, establish November 19, 1898, by H. A. Pressey and B. H. Flynn, is loca the highway bridge, near Waterville, Ohio. The gagings are from the upstream side of bridge, the zero being on the left ban marked by a nail in the guard rail. The wire gage is referre bench mark cut in upstream side of abutment on left side of rive elevation of which is 25.2 feet above the datum of the gage. Th *is rocky,* the current strong, and is unaffected by the backwater *the lake.* *The observer* is J. E. Harpel, Waterville, Ohio.

Mexico station on Sandusky River.—This station, established on November 17, 1898, by H. A. Pressey and B. H. Flynn, is at the highway bridge, near Mexico, about 40 miles above Fremont, Ohio, by river. The wire gage is on the upstream side of the bridge. It is referred to a bench mark, a cross cut in the top of upstream wing of right abutment of bridge. The elevation of bench mark is 30 feet above the datum of the gage. The gagings are made from the downstream side of bridge, the zero being on the right bank, marked by a nail in the guard rail. The bed of the river is rocky and the section unobstructed by piers. The observer is M. L. Estep.

Fremont station on Sandusky River.—This station, established on November 18, 1898, by H. A. Pressey and B. H. Flynn, is at the bridge of the Lake Shore Railway at Fremont. The gagings are made from board walk on lower cord of bridge, zero being a cross cut on bottom lateral at west end of bridge. The gage, an iron pipe graduated to feet and tenths, is located at the waterworks intake and referred to a bench mark cut on top of south end of west abutment of bridge. The elevation of bench mark is 20.1 feet above the datum of the gage. The bed is rocky and the banks high and not subject to overflow. The observer is Charles F. Reiff.

TABLES OF DAILY GAGE HEIGHT.

Daily gage height, in feet, of Maumee River at Waterville, Ohio, for 1898.

Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.
1	.....	2.55	9	.....	3.10	17	.....	3.80	25	2.90	8.45
2	.....	2.50	10	.....	2.50	18	.....	3.60	26	3.05	6.90
3	.....	2.60	11	.....	3.85	19	.....	2.90	27	2.55	6.70
4	.....	2.60	12	.....	3.40	20	3.80	3.60	28	2.70	6.00
5	.....	2.70	13	.....	3.25	21	3.60	5.60	29	2.65	5.10
6	.....	2.50	14	.....	3.85	22	3.55	7.80	30	2.60	4.70
7	.....	2.45	15	.....	3.95	23	3.15	9.40	31	.....	4.35
8	.....	2.40	16	.....	4.15	24	3.05	8.45			

Daily gage height, in feet, of Sandusky River at Mexico, Ohio, for 1898.

Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.
1	.....	1.50	9	.....	1.80	17	.....	1.50	25	1.60	5.10
2	.....	1.50	10	.....	1.80	18	2.20	1.50	26	1.60	4.50
3	.....	1.50	11	.....	1.80	19	2.10	1.60	27	1.60	3.40
4	.....	1.50	12	.....	1.80	20	2.00	6.30	28	1.50	3.10
5	.....	1.50	13	.....	1.80	21	1.90	11.90	29	1.50	3.00
6	.....	1.60	14	.....	1.70	22	1.80	13.00	30	1.50	2.90
7	.....	1.80	15	.....	1.70	23	1.80	9.90	31	.....	3.10
8	.....	1.80	16	.....	1.60	24	1.70	6.30			

Daily gage height, in feet, of Sandusky River at Fremont, Ohio, for 1898.

Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.
1	.....	1.10	9	.....	1.20	17	.....	1.00	25	1.25	2.65
2	.....	1.05	10	.....	1.00	18	2.00	.90	26	1.20	2.20
3	.....	1.00	11	.....	1.25	19	1.85	1.05	27	1.15	1.85
4	.....	1.10	12	.....	1.15	20	1.70	3.75	28	1.05	2.05
5	.....	1.35	13	.....	1.00	21	1.65	5.60	29	1.15	1.90
6	.....	1.60	14	.....	1.05	22	1.55	5.25	30	1.10	2.00
7	.....	*1.50*	*15*	.....	1.00	23	1.40	4.80	31	.....	2.10
8	.....	*1.15*	*16*	.....	1.00	24	1.30	3.50			

List of discharge measurements, 1898.

Date	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
				Feet.	*Sec.-feet.*
Nov. 19	Maumee River	Waterville, Ohio	H. A. Pressey	4.00	5,628
Nov. 17	Sandusky River	Mexico, Ohio	do	2.30	288
Nov. 18	do	Fremont, Ohio	do	2.00	645

UPPER MISSOURI RIVER DRAINAGE.

DESCRIPTION OF RIVER STATIONS.

Salesville station on West Gallatin River.—Described on page 66 of Paper No. 15; results for 1897 shown on pages 275–277 of the Nineteenth Annual Report, Part IV.

Bozeman station on Middle Creek.—Described on page 67 of Paper No. 15, and on page 271 of the Nineteenth Annual Report, Part IV. A wire cable was placed across the stream in 1898, 250 yards north of the gage station, and current meter measurements are made from this.

Logan station on Gallatin River.—Described on page 68 of Paper No. 15; results for 1897 shown on pages 277–278 of the Nineteenth Annual Report.

Redbluff station on Madison River.—Described on page 69 of Paper No. 15; results for 1897 shown on pages 279–280 of the Nineteenth Annual Report, Part IV.

Sappington station on Jefferson River.—Described on page 70 of Paper No. 15; results for 1897 shown on pages 281–283 of the Nineteenth Annual Report, Part IV. The observer since March 26, 1898 has been W. D. McClellan.

Townsend station on Missouri River.—Described on page 65 of Paper No. 15; results for 1897 shown on pages 283–285 of the Nineteenth Annual Report, Part IV.

Havre station on Milk River.—This station is at a point on Milk River about one-quarter mile northwest of Havre, Montana. Owing to the river changing its channel so often and banks dropping in, a special form of gage rod was erected by Mr. Cyrus C. Babb. This consists of a 4-inch by 4-inch timber placed horizontally on supports and extending out over the river 20 feet. This is graduated in feet and tenths, and over it is run a wire with a weight attached, which is lowered to the surface of the water when measurements are made. The wire gage has a length of 24.8 feet. The measurements for discharge are made by means of a cable of 200 feet span, swung across the river, on which a box is run by pulleys. This is so located that an excellent result can be obtained. No readings were had in 1898 when the water was above the normal height, as the "June rise" had subsided before the station was established, May 15, 1898. The observer is Henry O'Herren, rancher. The discharge measurements were made by C. W. Ling and others.

The old station at Chinook, described on page 73 of Paper No. 15, was maintained through 1897, but was found to be of doubtful value on account of the poor section and from the fact that a number of canals diverted water at points above. It was decided to move the station to Havre, the wire gage erected being similar to the one in use at Whitman station, on Wallawalla River, Washington. The horizontal timber or boom noted above extends over the bank, being made fast to two posts set firmly in the ground about 6 feet apart.

Livingston station on Yellowstone River.—Described on page 74 of Paper No. 15; results for 1897 shown on pages 287–289 of the Nineteenth Annual Report, Part IV.

Lovell station on Shoshone River.—Described on page 76 of Paper No. 15; results for 1897 shown on pages 290–293 of the Nineteenth Annual Report, Part IV.

Buffalo station on Clear Creek.—Described on page 78 of Paper No. 15; results for 1897 given on pages 297–298 of the Nineteenth Annual Report, Part IV.

Fort Niobrara station on Niobrara River.—Described on page 80 of Paper No. 15; results for 1897 shown on page 299 of the Nineteenth Annual Report, Part IV. No gage heights were observed during 1898.

TABLES OF DAILY GAGE HEIGHT.

Daily gage height, in feet, of West Gallatin River at Salesville, Montana, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	.....	.....	2.80	3.85	5.20	4.80	3.70	3.40	3.20	3.20	3.00
2	2.90	4.10	.....	2.80	3.70	5.30	4.80	3.70	3.40	3.20	3.20	3.00
3	.....	.....	2.90	2.80	3.55	5.30	4.80	3.65	3.40	3.20	3.10	3.00
4	.....	.....	2.90	2.80	3.50	5.30	4.80	3.60	3.35	3.20	3.10	3.00
5	3.00	.....	2.90	2.80	3.50	5.30	4.80	3.60	3.30	3.20	3.10	3.00
6	.....	3.60	2.90	2.80	3.50	5.25	4.80	3.60	3.30	3.20	3.10	3.00
7	.....	.....	2.90	2.90	3.70	5.10	4.80	3.50	3.30	3.20	3.10	2.00
8	.....	.....	2.90	2.90	3.80	5.15	4.80	3.50	3.30	3.20	3.10	3.00
9	.....	.....	2.90	3.00	3.90	5.30	4.70	3.50	3.30	3.20	3.00	2.95
10	2.90	.....	2.90	3.00	3.90	5.45	4.60	3.50	3.30	3.20	3.00	2.90
11	.....	3.10	2.90	3.10	4.20	5.95	4.50	3.50	3.30	3.20	3.05	2.90
12	.....	.....	2.90	3.10	4.40	6.45	4.60	3.50	3.25	3.20	3.10	2.90
13	.....	.....	2.80	3.20	4.50	6.80	4.85	3.50	3.20	3.20	3.10	2.90
14	2.90	.....	2.80	3.30	4.80	7.20	4.65	3.50	3.20	3.20	3.10	2.90
15	.....	.....	2.80	3.40	4.80	6.95	4.55	3.45	3.20	3.20	3.10	3.00
16	.....	3.00	2.80	3.40	5.00	7.45	4.45	3.40	3.20	3.20	3.10	3.15
17	.....	.....	2.80	3.40	5.00	7.45	4.40	3.40	3.20	3.20	3.10	3.30
18	.....	.....	2.80	3.40	5.00	7.15	4.30	3.40	3.20	3.20	3.10	3.40
19	3.00	.....	2.80	3.20	4.80	7.05	4.20	3.40	3.20	3.20	3.05	3.40
20	.....	2.90	2.70	3.20	4.80	6.85	4.10	3.40	3.20	3.20	3.00	3.50
21	.....	.....	2.70	3.30	4.80	6.60	4.10	3.30	3.20	3.20	3.00	3.50
22	.....	.....	2.70	3.20	4.80	6.30	4.10	3.30	3.20	3.20	3.00	3.50
23	3.10	2.90	2.70	3.15	5.30	6.20	4.10	3.30	3.20	3.20	3.10	3.50
24	.....	.....	2.70	3.20	5.40	6.55	4.00	3.30	3.20	3.20	3.10	3.50
25	.....	.....	2.80	3.50	5.60	6.20	3.95	3.30	3.20	3.20	3.00	3.40
26	.....	.....	2.80	3.90	5.80	5.55	3.90	3.30	3.20	3.20	3.00	3.40
27	.....	.....	2.80	4.05	5.80	5.05	3.90	3.30	3.20	3.20	3.00	3.35
28	3.10	2.90	2.70	4.05	5.90	4.95	3.80	3.30	3.20	3.20	3.00	3.15
29	.....	.....	2.70	4.00	6.20	4.80	3.80	3.40	3.20	3.20	3.00	3.00
30	.....	.....	2.70	3.90	5.85	4.80	3.80	3.40	3.20	3.30	3.00	3.00
31	.....	.....	2.70	.....	5.80	.....	3.75	3.40	.....	3.30	.....	3.00

Daily gage height, in feet, of Middle Creek at Bozeman, Montana, for 1898.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1		0.40	0.80	0.60	0.15	0.05	0.00		
2		.35	.90	.55	.15	.05	— .01		
3		.45	.80	.50	.15	.05	.00		
4		.35	.90	.50	.15	.03	.00		
5		.30	1.10	.70	.15	.03	.00	0.00	
6		.35	.80	.60	.10	.03	.00		
7		.40	.75	.65	.10	.05	.00		
8		.40	.75	.57	.10	.05	.00		
9		.43	.80	.60	.10	.03	.03		
10		.50	.40	.60	.10	.03	.03		
11		.60	.80	.60	.10	.03	.03		
12		.65	.95	.75	.10	.03	.03	.90	1.10
13		.70	.80	.65	.08	.03	.03		
14		.70	2.10	.50	.08	.03	.00		
15		.70	2.00	.50	.10	.03	— .01		
16		.80	1.90	.50	.10	.03	— .01		
17		1.00	1.30	.45	.10	.03	.00		
18	0.30	1.10	1.20	.40	.10	.03	.03		
19	.30	.90	1.20	.35	.10	.00	.05		—.05
20	.30	.80	1.10	.30	.10	— .01	.03		
21	.35	.80	1.00	.30	.08	— .01	.00	— .90	
22	.40	.80	1.00	.30	.05	.00	.03		
23	.42	.90	1.00	.30	.05	.00			
24	.46	.90	1.10	.30	.05	.00			
25	.65	.80	1.00	.30	.03	— .03			
26	.95	.75	.90	.25	.03	— .01			
27	.80	.90	1.00	.20	.03	.00			— .05
28	.60	.83	.90	.20	.03	.00			
29	.50	.75	.70	.20	.03	.00		1.00	
30	.46	.80	.65	.20	.03	.00			
31		.80		.18	.05				

Daily gage height, in feet, of Gallatin River at Logan, Montana, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.30		1.10	1.00	1.85	3.80	2.55	0.70	0.70	1.20	1.20	(a)
2			1.10	1.00	1.80	4.10	2.40	.70	.70	1.15	1.20	(a)
3			1.10	1.00	1.70	3.80	2.15	.70	.70	1.10	1.20	(a)
4			1.10	1.00	1.55	3.70	2.00	.70	.70	1.10	1.20	(a)
5			1.10	1.10	1.50	3.60	1.85	.70	.70	1.10	1.20	(a)
6			1.10	1.00	1.40	3.50	1.75	.70	.70	1.10	1.20	(a)
7		(b)	1.10	1.00	1.40	3.50	1.65	.70	.80	1.10	1.20	(a)
8	1.00		1.00	1.00	1.40	3.50	1.60	.70	.80	1.10	1.15	(a)
9			1.00	1.10	1.40	3.55	1.55	.70	.80	1.10	1.10	(a)
10			.95	1.35	1.50	3.70	1.50	.70	.90	1.10	1.10	(a)
11			1.00	1.55	1.55	3.95	1.50	.70	.90	1.10	1.10	(a)
12		1.00	1.00	1.45	1.80	4.30	1.50	.70	1.00	1.10	1.10	(a)
13			1.00	1.40	2.15	4.55	1.50	.70	1.00	1.20	1.10	(a)
14			1.00	1.50	2.25	4.75	1.60	.70	1.00	1.20	1.10	(a)
15	1.60		1.00	1.55	2.30	5.05	1.50	.70	1.00	1.20	1.10	(a)
16			1.00	1.60	2.50	5.20	1.40	.70	1.00	1.20	1.10	(a)
17		1.00	.90	1.50	2.80	5.15	1.35	.70	1.00	1.20	1.10	(a)
18			.90	1.40	3.00	5.20	1.15	.70	1.00	1.20	1.10	(a)
19		1.10	1.00	1.40	3.08	5.25	1.10	.70	1.00	1.20	1.10	(a)
20			1.00	1.40	3.00	5.25	1.00	.70	1.00	1.20	1.10	(a)
21			1.00	1.40	2.90	5.00	1.00	.70	1.00	1.20	1.10	(a)
22	1.60		1.00	1.40	2.70	4.30	.90	.70	1.00	1.20	(a)	(a)
23			1.00	1.40	2.85	4.10	.90	.70	1.00	1.20	(a)	(a)
24			1.00	1.40	3.00	4.30	.90	.70	1.00	1.20	(a)	(a)
25			1.00	1.50	3.00	4.15	.80	.70	1.00	1.20	(a)	(a)
26		1.00	1.00	1.70	3.15	3.90	.80	.70	1.00	1.20	(a)	(a)
27			1.00	1.95	3.50	3.55	.80	.70	1.10	1.20	(a)	(a)
28			1.00	2.00	3.60	3.30	.70	.70	1.10	1.20	(a)	(a)
29	(a)		1.00	1.90	3.90	2.85	.70	.70	1.10	1.20	(a)	(a)
30			1.00	1.90	4.25	2.65	.70	.70	1.10	1.20	(a)	(a)
31			1.00		3.90		.70			1.20		(a)

a Frozen at gage. *b* Ice flowed out February 7.

y gage height, in feet, of Madison River at Redbluff, Montana, for 1898.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
.....	.....	2.50	1.90	1.60	1.60	1.40	1.40	(a)
.....	.....	2.60	1.90	1.60	1.60	1.40	1.40	(a)
.....	.....	2.80	2.00	1.60	1.60	1.40	1.40	(a)
.....	.....	2.50	2.00	1.60	1.60	1.40	1.40	(a)
.....	.....	2.30	2.00	1.60	1.55	1.40	1.40	(a)
.....	.....	2.30	2.00	1.60	1.45	1.40	1.40	(a)
.....	1.65	2.20	2.00	1.60	1.40	1.40	1.40	(a)
.....	1.70	2.20	1.90	1.60	1.40	1.40	1.40	(a)
.....	1.70	2.20	1.95	1.60	1.40	1.40	1.40	(a)
.....	1.70	2.35	2.00	1.60	1.40	1.40	1.40	(a)
.....	1.70	2.40	2.00	1.60	1.40	1.40	1.40	(a)
.....	1.90	2.50	2.00	1.60	1.40	1.40	1.40	(a)
.....	2.00	2.55	2.10	1.60	1.40	1.40	1.40	(a)
.....	2.00	2.95	2.00	1.60	1.40	1.40	1.40	(a)
.....	2.10	2.95	2.00	1.60	1.40	1.40	(a)	(a)
.....	2.30	3.05	2.00	1.60	1.40	1.40	(a)	(a)
.....	2.50	3.15	2.00	1.70	1.40	1.40	(a)	(a)
.....	2.55	3.20	1.85	1.70	1.40	1.40	(a)	(a)
.....	2.60	3.20	1.80	1.70	1.40	1.40	(a)	(a)
.....	2.55	3.10	1.80	1.50	1.40	1.40	(a)	(a)
.....	2.35	3.00	1.80	1.50	1.40	1.40	(a)	(a)
.....	2.10	2.95	1.70	1.50	1.40	1.40	(a)	(a)
.....	2.10	2.65	1.75	1.50	1.40	1.40	(a)	(a)
.....	2.40	2.60	1.70	1.40	1.40	1.40	(a)	(a)
.....	2.30	2.50	1.70	1.40	1.40	1.40	(a)	(a)
.....	2.30	2.55	1.60	1.40	1.40	1.40	(a)	(a)
.....	2.50	2.30	1.60	1.40	1.40	1.40	(a)	(a)
.....	2.70	2.20	1.60	1.60	1.40	1.45	(a)	(a)
.....	2.70	2.00	1.60	1.55	1.40	1.45	(a)	(a)
.....	2.70	1.80	1.60	1.50	1.40	1.40	(a)	(a)
.....	2.55	.....	1.60	1.50	.....	1.40	(a)	(a)

a Frozen at gage.

ge height, in feet, of Jefferson River at Sappington, Montana, for 1898.

.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
.....	a 2.00	1.60	3.50	5.75	3.60	1.50	1.00	1.30	1.70	(b)
.....	1.70	1.60	3.35	5.60	3.75	1.40	1.00	1.30	1.70	(b)
.....	1.60	1.60	3.20	5.55	4.05	1.40	1.00	1.30	1.70	(b)
.....	1.60	1.65	3.05	5.35	4.05	1.30	1.75	1.30	1.70	(b)
.....	1.60	1.65	2.95	5.25	3.70	1.30	1.55	1.30	1.70	(b)
.....	1.60	1.70	2.85	5.05	3.40	1.30	1.50	1.30	1.70	(b)
.....	1.60	1.80	2.70	4.85	3.15	1.30	1.50	1.40	1.70	(b)
.....	1.65	1.80	2.70	4.65	2.95	1.20	1.50	1.40	1.70	(b)
.....	1.70	1.80	2.70	4.60	2.75	1.20	1.50	1.40	1.60	(b)
.....	1.60	1.80	2.70	4.55	2.70	1.20	1.50	1.45	1.60	(b)
.....	1.60	2.00	2.80	4.65	2.70	1.20	1.40	1.50	1.60	(b)
.....	1.60	2.10	2.85	4.75	2.75	1.10	1.40	1.50	1.60	(b)
.....	1.60	2.10	3.10	4.90	2.85	1.10	1.40	1.50	1.60	(b)
.....	1.60	2.15	3.30	5.40	2.95	1.10	1.40	1.50	1.60	(b)
.....	1.55	2.45	3.50	5.60	2.85	1.10	1.30	1.50	1.60	(q)
.....	1.50	2.75	3.75	5.75	2.80	1.10	1.30	1.55	1.60	(b)
.....	1.50	3.20	4.10	5.80	2.80	1.10	1.30	1.60	1.70	(b)
.....	1.50	3.65	4.25	5.80	2.80	1.00	1.30	1.60	1.70	(b)
.....	1.50	4.30	4.50	5.80	2.70	1.00	1.30	1.60	1.70	(b)
.....	1.50	3.85	4.65	5.75	2.55	1.00	1.30	1.60	1.70	(b)
.....	1.50	3.50	4.65	5.65	2.35	1.00	1.25	1.60	1.70	(b)
.....	1.50	3.50	4.60	5.50	2.25	1.00	1.20	1.60	1.70	(b)
.....	1.40	3.40	4.55	5.05	2.15	1.00	1.20	1.65	1.70	(b)
.....	1.35	3.30	4.85	4.85	2.00	1.00	1.20	1.70	1.70	(b)
.....	1.30	3.30	4.95	4.55	1.90	1.00	1.20	1.70	1.70	(b)
.....	1.30	3.40	4.75	4.35	1.80	1.00	1.20	1.70	1.70	(b)
.....	1.30	3.50	4.65	4.10	1.70	1.00	1.30	1.70	1.70	(b)
.....	1.45	3.55	4.95	3.80	1.70	1.00	1.30	1.70	1.70	(b)
.....	1.55	3.70	5.65	3.55	1.70	1.00	1.30	1.70	1.70	(b)
.....	1.65	3.65	6.05	3.50	1.60	1.00	1.30	1.70	1.85	(b)
.....	1.60	.....	5.90	.....	1.60	1.00	.....	1.70	.....	(b)

a River frozen from January 1 to February 28. *b* Frozen at gage.

Daily gage height, in feet, of Missouri River, at Townsend, Montana, for 1898. (a)

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	92.04	91.79	89.49	88.84	90.34	93.04	90.84	88.74	88.54	88.64	88.99
2	92.01	91.84	89.34	88.91	90.21	92.79	90.84	88.74	88.54	88.64	89.04
3	91.94	91.89	89.14	88.96	90.04	92.59	90.89	88.69	88.54	88.64	89.04
4	91.84	91.99	89.89	89.01	89.81	92.49	90.91	88.64	88.54	88.64	89.04
5	91.87	92.04	88.84	89.04	89.69	92.41	90.74	88.64	88.59	88.64	89.04
6	91.64	92.04	88.84	89.04	89.64	92.31	90.49	88.64	88.64	88.64	88.99
7	91.46	92.04	88.84	89.04	89.64	92.19	90.31	88.64	88.74	88.64	88.94
8	91.44	92.04	88.79	89.04	89.69	91.99	90.11	88.64	88.74	88.64	88.94
9	91.44	92.04	88.74	89.04	89.84	91.91	90.01	88.64	88.74	88.64	88.91
10	91.44	92.04	88.74	89.04	89.89	92.01	89.94	88.64	88.74	88.64	88.84
11	91.44	92.04	88.74	89.26	90.04	92.04	89.89	88.64	88.74	88.69	88.84
12	91.44	92.04	88.74	89.39	90.14	92.09	89.84	88.59	88.74	88.74	88.84
13	91.44	92.04	88.74	89.56	90.34	92.29	89.84	88.54	88.74	88.76	88.84
14	91.44	92.04	88.74	89.61	90.59	92.64	89.84	88.54	88.74	88.84	88.84
15	91.51	92.04	88.74	89.64	90.69	92.96	89.84	88.54	88.74	88.84	88.79
16	91.54	92.04	88.74	89.71	90.64	93.29	89.84	88.54	88.74	88.84	88.74
17	91.54	91.99	88.74	90.06	90.54	93.49	89.84	88.54	88.69	88.84	88.74
18	91.54	91.94	88.74	90.24	90.46	93.64	89.71	88.54	88.69	88.84	88.74
19	91.54	91.94	88.74	90.49	90.44	93.54	89.51	88.54	88.66	88.89	b88.74
20	91.56	91.94	88.74	90.46	90.41	93.46	89.44	88.54	88.64	88.91	.....
21	91.61	92.01	88.74	90.26	90.34	93.29	89.39	88.54	88.64	88.94	.....
22	91.71	92.04	88.74	90.21	90.59	93.09	89.34	88.54	88.64	88.96	.....
23	91.74	92.04	88.74	90.19	90.89	92.89	89.26	88.54	88.64	88.99	.....
24	91.74	92.04	88.74	90.16	91.24	92.49	89.16	88.54	88.64	88.99	.....
25	91.74	92.04	88.86	90.14	91.54	92.09	89.09	88.54	88.64	89.04	.....
26	91.74	89.79	92.04	90.21	91.74	91.91	89.04	88.54	88.64	89.04	.....
27	91.74	89.59	92.04	90.24	92.29	91.81	88.96	88.49	88.64	89.04	.....
28	91.74	89.54	92.04	90.24	92.59	91.34	88.89	88.49	88.64	89.04	.....
29	91.74	.....	88.74	90.31	92.79	90.74	88.81	88.54	88.64	89.04	.....
30	91.74	.....	88.74	90.34	92.86	90.79	88.74	88.54	88.64	89.04	.....
31	91.74	.....	88.79	.....	92.99	.....	88.74	88.54	.....	89.04	.....

a Readings taken to surface of ice from January 1 to February 25, and from March 28 to [illegible]
b Discontinued.

Daily gage height, in feet, of Milk River at Havre, Montana, for 1898.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	3.75	1.90	1.30	1.00	0.50	1.30	.....
2	.....	3.70	1.90	1.30	1.00	.50	1.30	.....
3	.....	3.90	1.85	1.25	1.20	.85	1.30	.....
4	.....	3.75	1.70	1.20	1.30	1.05	1.30	.....
5	.....	3.60	1.70	1.20	1.20	1.10	1.30	1.50
6	.....	3.40	1.65	1.30	1.35	1.20	1.30	1.50
7	.....	3.30	1.70	1.30	1.20	1.20	1.30	1.50
8	.....	3.10	1.50	1.20	1.10	1.20	1.30	1.50
9	.....	3.00	1.50	1.10	1.00	1.20	1.40	1.50
10	.....	2.90	.50	1.10	.90	1.25	1.30	1.50
11	.....	2.90	.40	1.10	1.00	1.30	1.30	1.40
12	.....	2.75	.40	1.10	1.00	1.40	1.30	1.40
13	.....	2.65	.30	1.00	.80	1.50	1.40	1.40
14	.....	2.70	.80	1.00	.80	1.40	1.30	1.40
15	2.90	2.75	1.30	.90	.85	1.30	1.25	1.40
16	2.90	3.10	(a)	.90	.85	1.30	1.25	1.40
17	3.40	2.75	(a)	.80	.80	1.20	1.30	1.40
18	3.25	2.65	(a)	.80	.80	1.10	1.35	1.40
19	3.10	2.60	1.35	.80	.80	1.10	1.30	1.40
20	3.80	2.75	1.55	.80	.75	1.10	.....	1.40
21	3.20	2.85	1.70	.80	.70	1.00	.....	1.40
22	3.00	2.60	1.60	.70	.70	1.15	.....	1.40
23	3.00	2.50	1.60	.70	.70	1.30	.....	1.40
24	2.85	2.45	2.50	2.45	.65	1.25	.....	1.40
25	2.70	2.45	1.90	2.05	.70	1.40	.....	.....
26	2.40	2.40	1.90	1.75	.70	1.40	.....	1.40
27	2.55	2.30	1.80	1.60	.70	1.50	.....	1.40
28	2.50	2.20	1.65	1.30	.70	1.40	.....	.....
29	2.60	2.05	1.45	1.15	.60	1.40	.....	.....
30	2.50	1.80	1.35	1.00	.50	1.40	.....	.....
31	2.50	.....	1.30	1.00	.....	1.30	.....	1.40

a July 16, 17, 18 river changed channel, leaving gage without water.

Daily gage height, in feet, of Yellowstone River at Livingston, Montana, for 1893.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	.....	1.15	1.10	2.65	5.05	5.25	3.13	2.38	1.60	1.20	0.95
2	.....	.....	1.10	1.10	2.45	4.88	5.25	3.08	2.25	1.60	1.20	.....
3	.....	.....	1.08	1.10	2.33	4.75	5.13	3.03	2.28	1.48	1.20	.....
4	.....	0.90	1.05	1.10	2.20	4.50	5.03	2.98	2.33	1.48	1.20	.....
5	.....	.....	1.05	1.08	2.15	4.60	4.98	2.90	2.25	1.45	1.20	.....
6	.....	.....	1.10	1.05	2.08	4.38	4.98	2.90	2.13	1.45	1.20	.....
7	0.90	.....	1.10	1.05	2.15	4.38	4.88	2.85	2.05	1.40	1.20	.....
8	.....	.....	1.10	1.10	2.43	4.53	4.83	2.78	2.00	1.40	1.20	.....
9	.....	.....	1.10	1.08	2.63	4.83	4.83	2.75	2.00	1.40	.90	.....
10	.....	.....	1.00	1.15	2.70	5.05	4.65	2.70	1.90	1.45	.90	.....
11	.....	.85	1.00	1.25	3.38	5.33	4.60	2.65	1.85	1.50	1.15	.....
12	.....	.....	1.00	1.25	3.83	5.45	4.63	2.60	1.85	1.55	1.10	.....
13	.....	.....	.95	1.25	3.88	5.68	4.83	2.55	1.85	1.50	1.05	.....
14	.65	.....	.95	1.40	3.93	6.30	4.63	2.55	1.80	1.48	1.05	.....
15	.....	.....	.90	1.55	4.18	6.70	4.58	2.55	1.80	1.45	1.05	.....
16	.....	.....	.90	1.80	4.25	6.85	4.50	2.58	1.80	1.40	1.10	.....
17	.....	.....	.82	1.83	4.40	7.15	4.35	2.60	1.80	1.40	1.13	.....
18	.....	.90	.85	1.85	4.30	7.55	4.20	2.58	1.75	1.40	1.10	.80
19	.....	.....	.90	1.78	4.25	7.55	4.10	2.48	1.75	1.35	1.10	.....
20	.....	.....	.90	1.70	4.10	7.38	3.85	2.43	1.70	1.30	(a)	.....
21	.85	.....	.80	1.75	3.90	6.65	3.85	2.35	1.68	1.30	(a)	.....
22	.....	.....	(a)	1.83	3.75	6.25	3.75	2.30	1.65	1.30	(a)	.80
23	.....	.....	(a)	1.95	4.05	6.35	3.70	2.30	1.60	1.30	.95	.....
24	.....	.....	(a)	1.88	4.78	6.50	3.65	2.28	1.60	1.30	.90	.....
25	.....	1.15	(a)	1.95	4.78	6.40	3.60	2.20	1.60	1.25	.90	.....
26	.....	.....	(a)	2.48	4.98	5.85	3.53	2.15	1.55	1.25	(a)	.....
27	.....	.....	(a)	3.15	5.33	5.55	3.48	2.15	1.53	1.20	(a)	.....
28	.90	.....	(a)	3.03	5.90	5.53	3.38	2.60	1.50	1.20	.95	.....
29	.....	.....	(a)	2.85	5.68	5.38	3.33	2.30	1.50	1.20	.98	.80
30	.....	.....	1.10	2.83	5.38	5.25	3.23	2.30	1.50	1.20	.95	.....
31	.....	.....	1.10	.....	5.30	.....	3.15	2.68	.....	1.20	.....	.....

a Ice gorge in river.

Daily gage height, in feet, of Shoshone River at Lovell, Wyoming, for 1893.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Day.	Apr.	May.	June.	July.	Aug.	Sept.
1	−0.80	0.00	1.30	1.60	0.10	+0.40	17	+0.20	1.70	3.00	1.60	−0.40	−0.90
2	− .80	.00	1.40	1.40	.20	− .30	18	+ .00	1.70	3.50	1.30	+ .10	−1.00
3	− .90	−.40	1.40	1.30	.30	+ .50	19	− .80	3.00	3.60	.80	− .30	−1.00
4	− .80	−.30	1.20	1.30	.50	− .10	20	− .80	2.70	3.50	.70	− .50	−1.10
5	− .80	−.40	1.40	1.70	.30	− .40	21	− .90	1.80	3.30	.70	− .60	−1.10
6	− .80	−.40	1.00	2.00	.30	− .40	22	− .30	1.80	3.00	.70	− .60	−1.10
7	− .60	−.40	.90	2.20	.10	− .80	23	− .80	1.70	3.40	.60	− .60	−1.20
8	− .70	−.30	.90	2.10	.20	− .80	24	− .30	2.80	3.20	.60	− .70	−1.20
9	− .70	−.30	1.30	2.10	.30	− .80	25	− .30	2.30	3.20	.60	− .80	−1.20
10	− .50	+.10	1.80	2.30	.40	− .80	26	+ .70	2.20	3.00	.40	− .90	−1.20
11	− .50	.80	1.90	2.40	.40	− .90	27	1.00	2.20	2.50	.40	− .90	−1.20
12	− .50	.70	2.20	2.20	.50	− .90	28	.70	4.00	2.50	.30	+ .10	−1.20
13	− .30	.50	2.10	2.60	.60	− .90	29	.20	2.20	2.00	.20	.70	−1.30
14	− .20	1.00	2.70	2.40	.50	− .90	30	.10	2.20	2.30	.10	.30	−1.30
15	+ .10	1.00	2.80	2.10	.40	− .90	31	.....	1.60	.....	.10	.40	.....
16	+ .30	.70	3.20	2.00	− .40	− .90							

Daily gage height, in feet, of Clear Creek at Buffalo, Wyoming, for 1893.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	.....	.....	.....	.....	2.45	1.35	0.80	0.30	.....	.....	.....
2	.....	.....	.....	.....	.....	2.48	1.30	.85	.30	.....	.....	.....
3	.....	.....	.....	.....	.....	2.10	1.30	.80	.30	.....	0.43	0.38
4	.....	.....	.....	.....	.....	2.10	1.30	.80	.35	.....	.....	.....
5	.....	.....	.....	.....	.....	1.70	.....	.80	.35	.....	.....	.....
6	0.37	.....	0.35	.....	.....	1.95	.....	.80	.35	0.60	.....	.....
7	.....	0.32	.....	.....	.....	1.70	.....	.80	.35	.60	.....	.....
8	.....	.....	.....	.....	.....	1.60	.....	.85	.35	.55	.....	.....
9	.....	.....	.....	.....	.....	2.00	.....	.80	.40	.55	.....	.....
10	.....	.....	.....	.....	.....	2.10	1.22	.70	.40	.55	.42	.....
11	.....	.....	.....	.....	.....	1.90	1.15	.65	.40	.55	.....	.35
12	.....	.34	.....	.....	.....	2.20	1.15	.70	.40	.55	.....	.....
13	.....	.....	.35	.....	.....	2.60	1.25	.70	.40	.55	.....	.....

Daily gage height, in feet, of Clear Creek at Buffalo, Wyoming, for 1898—Cont'd.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
14						(a)	1.25	.50	.40	.55		
15	.35				0.95	2.45	1.30	.45	.40	.55		
16					1.15	2.45	1.45	.45	.45	.55		
17					1.47	2.60	1.25	.50	.45	.50	.40	
18					1.35	2.20	1.15	.50	.45	.55		.32
19					1.30	2.10	1.10	.50	.45	.55		
20			.37		1.45	2.10	1.05	.50	.45	.55		
21		.34			1.30	2.10	1.00	.45	.50	.55		
22	.35				1.30	1.95	1.00	.40	.50	.55		
23					1.30	1.95	1.00	.40	.50	.55		
24					2.65	1.90	1.00	.40	.50	.50		
25					2.70	1.75	.95	.40	.50	.50	.40	
26					2.60	1.70	.95	.40	.45	.50		.32
27		.35	.40			1.55	.90	.40	.45	.50		
28						1.50	.90	.40	.45			
29					3.00	1.45	.85	.40				
30	.30				(a)	1.45	.85	.35				
31					2.09		.80	.30				

a High water.

List of discharge measurements, 1898.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
				Feet.	*Sec.-feet.*
Apr. 17	West Gallatin River.	Salesville, Mont	Roe Emery	3.40	942
June 9	do	do	do	5.40	3,625
June 18	do	do	C. C. Babb	7.20	6,759
July 18	do	do	Roe Emery	4.30	1,734
Aug. 12	do	do	do	3.50	935
Sept. 7	do	do	do	3.35	1,010
Sept. 23	do	do	do	3.25	961
Oct. 9	do	do	do	3.20	653
Oct. 26	do	do	do	3.30	622
Nov. 16	do	do	do	3.10	480
Apr. 16	Middle Creek	Bozeman, Mont	do	.30	65
May 22	do	do	do	.85	225
June 17	do	do	C. C. Babb	1.20	482
July 17	do	do	Roe Emery	.40	223
Aug. 2	do	do	do	.15	86
Aug. 4	do	do	do	.12	79
Aug. 14	do	do	do	.07	51
Sept. 6	do	do	do	.05	71
Sept. 21	do	do	do	.00	81
Oct. 9	do	do	do	.05	76
Oct. 25	do	do	do	.02	79
Nov. 5	do	do	do	.05	80
Apr. 21	Gallatin River	Logan, Mont	do	1.40	989
May 18	do	do	do	3.05	2,823
June 7	do	do	do	3.50	3,718
June 23	do	do	C. C. Babb	4.10	4,900
July 23	do	do	Roe Emery	.90	595
Aug. 6	do	do	do	.70	356
Aug. 17	do	do	do	.70	381
Sept. 11	do	do	do	.90	567
Sept. 24	do	do	do	1.00	1,025
Oct. 5	do	do	do	1.10	861
Oct. 29	do	do	do	1.20	779
Nov. 12	do	do	do	1.10	689
Apr. 30	Madison River	Redbluff, Mont	do	1.40	2,680
June 10	do	do	do	2.40	5,542
June 25	do	do	C. C. Babb	2.60	5,895
July 20	do	do	Roe Emery	1.60	2,849
Aug. 10	do	do	do	1.40	a 2,120
Sept. 9	do	do	do	1.40	1,956
Sept. 29	do	do	do	1.40	1,928
Oct. 10	do	do	do	1.40	2,299
Nov. 17	do	do	do	1.40	1,784
Apr. 21	Jefferson River	Sappington, Mont	do	3.52	5,007
June 24	do	do	C. C. Babb	4.70	7,700
July 23	do	do	Roe Emery	2.17	2,551
Aug. 8	do	do	do	1.20	1,079
Sept. 10	do	do	do	1.35	1,100
Sept. 16	do	do	do	1.30	1,184
Oct. 7	do	do	do	1.40	1,209

a Cherry Creek at Redbluff on August 10 discharged 5 second-feet.

List of discharge measurements, 1898—Continued.

.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
				Feet.	*Sec.-feet.*
29	Jefferson River	Sappington, Mont.	Roe Emery	1.70	1,538
11	do	do	do	1.60	1,386
20	Missouri River	Townsend, Mont	do	90.52	7,775
26	do	do	do	91.80	15,976
3	do	do	C. C. Babb	90.90	8,954
26	do	do	Roe Emery	89.10	4,778
5	do	do	do	88.70	2,494
30	do	do	do	88.60	2,421
17	do	do	do	88.75	2,721
8	do	do	do	88.70	3,034
22	do	do	do	89.00	3,749
10	do	do	do	88.90	2,709
26	Milk River	Havre, Mont.	do	5.70	1,701
24	do	do	do	2.80	1,306
29	do	do	C. C. Babb	1.95	171
29	do	do	do	1.40	145
4	do	do	C. W. Ling	.60	118
13	do	do	do	.40	77
24	do	do	do	2.00	457
26	do	do	do	1.70	194
5	do	do	do	1.20	106
24	do	do	do	.60	44
30	do	do	do	.80	31
4	do	do	do	1.40	96
6	do	do	do	1.50	105
10	do	do	do	1.60	119
12	do	do	do	1.70	132
13	do	do	do	1.80	158
14	do	do	do	1.70	125
30	do	do	do	1.10	89
24	do	do	do	1.30	120
26	do	do	do	1.50	133
1	do	do	do	1.40	115
14	do	do	do	1.10	64
15	do	do	do	1.20	84
16	do	do	do	1.10	86
17	do	do	do	1.10	92
18	do	do	do	1.10	83

Rating tables.

sville.	Bozeman.		Logan.		Redbluff.		Sappington.	
Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Sec.-feet.	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*
1,745	—0.5	335	0.5	200	1.0	850	1.2	1,080
1,919	—.4	350	.6	280	1.1	1,175	1.3	1,150
2,093	—.3	365	.7	370	1.2	1,500	1.4	1,230
2,267	—.2	380	.8	460	1.3	1,825	1.5	1,310
2,441	—.1	395	.9	550	1.4	2,150	1.6	1,390
2,615	.0	410	1.0	640	1.5	2,475	1.7	1,540
2,789	.1	425	1.1	730	1.6	2,800	1.8	1,700
2,963	.2	440	1.2	820	1.7	3,125	1.9	1,900
3,137	.3	455	1.3	910	1.8	3,450	2.0	2,100
3,311	.4	470	1.4	1,000	1.9	3,775	2.1	2,300
3,485	.5	485	1.5	1,120	2.0	4,100	2.2	2,500
3,659	.6	500	1.6	1,240	2.1	4,425	2.3	2,700
3,833	.7	515	1.7	1,360	2.2	4,750	2.4	2,900
4,007	.8	530	1.8	1,480	2.3	5,075	2.5	3,100
4,181	.9	545	1.9	1,600	2.4	5,400	2.6	3,300
4,355	1.0	560	2.0	1,720	2.5	5,725	2.7	3,500
4,529	1.1	575	2.2	1,990	2.6	6,050	2.8	3,700
4,703	1.2	590	2.4	2,260	2.7	6,375	2.9	3,900
5,051	1.3	605	2.6	2,530	2.8	6,700	3.0	4,100
5,399	1.4	620	2.8	2,800	2.9	7,025	3.2	4,500
5,747	1.5	635	3.0	3,070	3.0	7,350	3.4	4,900
6,095	1.6	650	3.2	3,340	3.1	7,675	3.6	5,300
6,443	1.7	665	3.4	3,610	3.2	8,000	3.8	5,700
6,791	1.8	680	3.6	3,880	3.3	8,325	4.0	6,120
7,139	1.9	695	3.8	4,150	3.4	8,650	4.2	6,520
7,487	2.0	710	4.0	4,420	3.5	8,975	4.4	6,920
7,835	2.1	725	4.2	4,690	.....	.....	4.6	7,320
8,183	2.2	740	4.4	4,960	.....	.....	4.8	7,720
.....	2.3	755	4.6	5,230	.....	.....	5.0	8,120
.....	2.4	770	4.8	5,500	.....	.....	.....	.....

Rating tables—Continued.

Townsend.		Havre.		Livingston.		Lovell.		Buffalo.	
Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*
88.0	1,200	0.4	0	1.0	1,900	−0.8	310	0.1	4
88.2	1,500	.5	11	1.2	2,192	−.7	360	.2	9
88.4	1,900	.6	22	1.4	2,484	−.6	430	.3	17
88.6	2,390	.7	33	1.6	2,776	−.5	500	.4	25
88.8	3,030	.8	44	1.8	3,068	−.4	600	.5	33
89.0	3,670	.9	55	2.0	3,360	−.3	700	.6	46
89.2	4,310	1.0	66	2.2	3,652	−.2	800	.7	64
89.4	4,950	1.1	77	2.4	3,944	−.1	920	.8	82
89.6	5,620	1.2	88	2.6	4,236	−.0	1,080	.9	104
89.8	6,320	1.3	99	2.8	4,528	.1	1,250	1.0	134
90.0	7,020	1.4	110	3.0	4,820	.2	1,450	1.1	169
90.2	7,720	1.5	125	3.2	5,112	.3	1,650	1.2	209
90.4	8,420	1.6	140	3.4	5,404	.4	1,900	1.3	246
90.6	9,120	1.7	165	3.6	5,750	.5	2,190	1.4	286
90.8	9,820	1.8	200	3.8	6,200	.6	2,480	1.5	323
91.0	10,570	1.9	280	4.0	6,850	.7	2,770	1.6	365
91.2	11,410	2.0	380	4.2	7,773	.8	3,060	1.7	406
91.4	12,360	2.1	494	4.4	8,696	.9	3,350	1.8	447
91.6	13,380	2.2	608	4.6	9,620	1.0	3,640	1.9	504
91.8	14,460	2.3	722	4.8	10,543	1.2	4,220	2.0	558
92.0	15,660	2.4	836	5.0	11,467	1.4	4,800	2.1	607
92.2	16,770	2.5	950	5.2	12,390	1.6	5,380	2.2	657
92.4	17,900	2.6	1,064	5.4	13,313	1.8	5,960	2.3	705
92.6	19,030	2.7	1,178	5.6	14,237	2.0	6,540	2.4	752
92.8	20,160	2.8	1,292	5.8	15,160	2.2	7,120	2.5	803
93.0	21,290	2.9	1,406	6.0	16,084	2.4	7,700	.....	.....
93.2	22,420	3.0	1,520	6.2	17,008	2.6	8,280	.....	.....
93.4	23,560	.....	.....	6.4	17,931	2.8	8,860	.....	.....
93.6	24,720	.....	.....	6.6	18,854	3.0	9,440	.....	.....
93.8	25,880	.....	.....	6.8	19,778	.....	.....	.....	.....

PLATTE RIVER DRAINAGE.

DESCRIPTION OF RIVER STATIONS.

Woods Landing station on Laramie River.—Described on page 81 of Paper No. 15; results for 1897 given on pages 300–302 of the Nineteenth Annual Report, Part IV.

Uva station on Laramie River.—Described on page 82 of Paper No. 15; results for 1897 given on pages 302–304 of the Nineteenth Annual Report, Part IV.

Orin Junction station on North Platte River.—Described on page 83 of Paper No. 15; results for 1897 given on pages 304–307 of the Nineteenth Annual Report, Part IV.

Gering station on North Platte River.—Described on page 84 of Paper No. 15; results for 1897 given on pages 304–308 of the Nineteenth Annual Report, Part IV. This station was discontinued October 31, 1898.

Camp Clarke station on North Platte River.—Described on page 85 of Paper No. 15; results for 1897 given on pages 308–310 of the Nineteenth Annual Report, Part IV.

North Platte station on North Platte River.—Described on page 86 of Paper No. 15; results for 1897 given on page 310 of the Nineteenth Annual Report, Part IV. The observer since May 7, 1898, has been H. E. Dress.

Morrison station on Bear Creek.—Described on page 91 of Paper No. 15; results for 1897 given on page 317 of the Nineteenth Annual Report, Part IV. It is located in the upper part of the town of Morrison, Colorado, but has not been maintained in 1898, owing to the fact that the Denver Union Water Company has given a report of the discharge of the creek at their head gates, about one-half mile above the town.

Marshall station on South Boulder Creek.—Described on page 91 of Paper No. 15; results for 1897 shown on page 318 of the Nineteenth Annual Report, Part IV. The discharges of the Community, and of the South Boulder and Coal Creek ditches should be added to that of the creek in order to obtain the total discharge at this point.

Boulder station on Boulder Creek.—Described on page 92 of Paper No. 15; results for 1897 given on pages 319–320 of the Nineteenth Annual Report, Part IV.

Lyons station on St. Vrain Creek.—Described on page 93 of Paper No. 15; results for 1897 given on pages 320–321 of the Nineteenth Annual Report, Part IV. The discharge of Supply ditch should be added to that of St. Vrain Creek to obtain the total discharge of the latter.

Arkins station, on Big Thompson Creek.—Described on page 94 of Paper No. 15; results for 1897 given on pages 321–322 of the Nineteenth Annual Report, Part IV. The discharges of Home Supply and Handy ditches should be added to that of Big Thompson River to obtain total discharge of the latter.

Denver station on South Platte River.—Described on page 88 of Paper No. 15; results for 1897 given on pages 311–315 of the Nineteenth Annual Report, Part IV. Another inclined gage rod reading the same as the one on the right bank was placed on the left side in August and is now in use. It consists of a 4 by 4 inch by 12 foot timber fastened to posts driven into the left bank and graduated to vertical feet and tenths.

Orchard station on South Platte River.—Described on page 89 of Paper No. 15; results for 1897 given on pages 315–316 of the Nineteenth Annual Report, Part IV. Another rod was placed at the wagon bridge on April 24, 1898, and is now in use. It consists of a vertical 2 by 6 inch by 5 feet 4 inch timber, fastened by spikes to a pile of the bridge at about the center of the channel, on the downstream side of the bridge. The rod is marked in tenths. The new gage rod is securely fastened by means of heavy spikes driven into a pile on east side of bridge near the 300-foot mark. The channel is straight for several hundred feet above and below, but both banks are low and liable to overflow. The bed of the stream is sandy and shifting and liable to serious changes. The gagings are aken either from the lower side of the bridge or by wading. The

gage observer is still Mrs. U. E. Foley, who lives at a distance of about one-fourth mile and who reads the rod once each day.

Columbus station on Loup River.—Described on page 97 of Paper No. 15; results for 1897 given on pages 323–333 of the Nineteenth Annual Report, Part IV. No rating table was constructed for this station, there being no constant relation between discharge and gage height. The mean daily discharges were computed by the indirect method outlined in the Nineteenth Annual Report, Part IV, pages 324–333.

Columbus station on Platte River.—Described on page 98 of Paper No. 15; results for 1897 given on pages 333–334 of the Nineteenth Annual Report, Part IV. No rating table was constructed for this station, there being no constant relation between discharge and gage height. The mean daily discharges were computed by the indirect method outlined in the Nineteenth Annual Report, Part IV, pages 324–331.

Norfolk station on Elkhorn River.—Described on page 99 of Paper No. 15; results for 1897 given on pages 334–335 of the Nineteenth Annual Report, Part IV. The observer is Burr Taft. No rating table was constructed for this station, there being no constant relation between discharge and gage height. The mean daily discharges were computed by the indirect method outlined in the Nineteenth Annual Report, Part IV, pages 324–331.

TABLES OF DAILY GAGE HEIGHT.

Daily gage height, in feet, of Laramie River at Woods Landing, Wyoming, for 18

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	0.80	1.30	2.35	1.20	0.50	0.30	0.40
2	.80	1.25	2.50	1.20	.40	.30	.40
3	.80	1.20	2.55	1.10	.40	.30	.40
4	.80	1.10	2.40	1.10	.40	.30	.40
5	.80	1.00	2.45	1.00	.40	.30	.40
6	.80	1.00	2.50	1.00	.40	.30	.40
7	.80	1.05	2.45	1.00	.40	.30	.40
8	.80	1.15	2.55	.90	.40	.30	.40
9	.80	1.20	2.35	.90	.40	.30	.40
10	.80	1.30	2.20	.85	.40	.30	.40
11	.80	1.40	2.30	.80	.40	.30	.40
12	.80	1.50	2.35	.80	.40	.30	.40
13	.90	1.55	2.35	.80	.40	.30	.40
14	.95	1.70	2.60	.80	.40	.30	.40
15	1.05	2.00	2.50	.70	.40	.30	.40
16	1.00	2.20	2.50	.70	.40	.30	.40
17	1.10	2.35	2.40	.70	.40	.30	.40
18	1.05	1.90	2.40	.70	.40	.30	.40
19	.95	1.70	2.35	.70	.40	.30	.40
20	1.00	1.75	2.30	.70	.40	.30	.40
21	1.00	1.85	2.20	.70	.40	.30	.....
22	1.00	1.95	2.15	.70	.40	.30	.....
23	1.00	2.00	2.05	.60	.40	.30	.....
24	1.00	2.30	1.95	.60	.40	.30	.....
25	1.00	2.65	1.75	.60	.40	.30	.....
26	1.05	2.75	1.60	.60	.30	.30	.....
27	1.15	2.65	1.45	.50	.30	.30	.....
28	1.35	2.40	1.40	.50	.30	.30	.....
29	1.50	2.20	1.30	.50	.30	.30	.....
30	1.40	2.40	1.30	.50	.30	.30	.....
31	.....	2.45	.....	.50	.30	.....	.....

gage height, in feet, of Laramie River at Uva, Wyoming, for 1898.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
.....	1.10	1.10	3.50	1.20	0.20	0.30	0.30	.....	0.70
.....	1.10	1.10	3.30	1.10	.20	.30	.30	.....	.....
.....	1.20	1.20	3.10	1.10	.20	.30	.35	.....	.....
.....	1.20	1.40	3.10	1.10	.20	.30	.35	.....	.....
.....	1.20	1.40	3.20	1.00	.15	.30	.35	.....	.....
.....	1.20	1.40	3.30	1.00	.10	.30	.30	0.40	.....
.....	1.10	1.30	3.40	1.00	.20	.30	.30	.45	.....
.....	1.10	1.30	3.20	.90	.20	.30	.30	.45	.80
.....	1.05	1.30	3.00	1.20	.20	.30	.30	.50	.70
.....	1.10	1.40	2.80	1.10	.25	.30	.35	.55	.....
.....	1.40	1.30	2.80	1.00	.30	.30	.35	.60	.....
.....	1.70	1.30	3.20	1.00	.30	.30	.35	.60	.....
.....	1.80	1.30	3.40	1.00	.40	.30	.40	.60	.....
.....	1.60	1.60	3.10	.90	.40	.35	.40	.60	.....
.....	1.50	2.40	3.20	1.00	.50	.35	.40	.70	.80
.....	1.50	2.10	3.40	.90	.50	.35	.40	.70	.....
.....	1.50	2.00	3.30	.90	.50	.30	.40	.70	.....
.....	1.40	2.00	3.20	.80	.45	.30	.45	.60	.70
.....	1.40	2.20	3.10	.80	.40	.30	.45	.60	.....
.....	1.20	2.60	3.00	.70	.40	.30	.45	.60	.....
.....	1.20	2.70	2.90	.60	.40	.30	.40	.60	.....
.....	1.20	2.40	2.80	.60	.40	.30	.40	.60	.80
.....	1.10	2.50	2.60	.60	.40	.30	.40	.55	.....
.....	1.10	2.80	2.40	.60	.35	.35	.40	.55	.....
.....	1.10	3.00	2.20	.60	.30	.35	.40	.60	.....
.....	1.10	3.10	2.00	.50	.30	.35	.35	.60	.....
.....	1.10	3.40	1.90	.40	.30	.30	.35	.....	.....
.....	1.10	3.80	1.70	.40	.30	.30	.35	.....	.70
.....	1.10	3.80	1.50	.30	.30	.30	.30	.....	.80
.....	1.10	3.70	1.30	.30	.30	.30	.....	.....	.....
.....	.....	3.70	.....	.20	.30	.....	.....	.....	.....

age height, in feet, of North Platte River at Orin, Wyoming, for 1898.

y.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
.....	.....	.....	0.90	.....	4.63	3.45	0.85	0.35	0.68	0.85	.....
.....	.....	.....	.90	3.03	4.35	3.10	.80	.35	.....	.85	.....
.....	.....	.....	.90	3.10	4.25	.....	.75	.35	.....	.85	.....
.....	.....	.....	.90	3.10	4.20	2.75	.75	.....	.....	.90	.....
.....	.....	1.30	.90	3.25	.....	2.43	.75	.30	.....	.95	.....
.....	.....	.....	.90	3.20	4.50	2.28	.75	.30	.....	.....	.....
.....	.....	.....	1.03	3.13	4.55	2.20	.....	.30	.....	.....	0.85
.....	.....	.....	1.08	.....	4.45	2.08	.70	.30	.....	.....	.....
.....	.....	.....	1.17	3.00	4.18	1.93	.65	.30	.....	.....	.....
.....	.....	.....	1.17	3.00	4.08	.....	1.15	.25	.70	.....	.....
.....	.....	.....	1.25	3.00	4.00	1.83	.98	.....	.....	.....	.....
.....	.....	.90	1.30	3.00	.....	1.68	.80	.20	.....	.....	.....
.....	.....	.....	1.45	3.10	4.28	1.63	.88	.20	.....	.85	.....
.....	.....	.....	1.80	3.25	4.30	1.80	.....	.20	.....	.....	.90
.....	.....	.....	2.20	.....	4.45	2.10	.80	.20	.....	.....	.....
.....	.....	.....	2.50	3.60	4.70	1.85	.80	.20	.....	.....	.....
.....	.....	.....	.....	4.00	4.50	.....	.73	.20	.....	.....	.....
.....	.....	.....	2.75	4.10	4.40	1.73	.70	.....	.....	.....	.....
.....	.....	.75	3.00	4.05	.....	1.63	.65	.20	.75	.....	.....
.....	.....	.....	3.40	4.10	4.50	1.53	.60	.20	.....	.....	.....
.....	.....	.....	3.60	4.25	4.50	1.43	.....	.20	.....	.90	.95
.....	.....	.....	3.60	.....	4.35	1.33	.55	.20	.....	.....	.....
.....	.....	.....	3.60	4.00	4.30	1.23	.50	.20	.....	.....	.....
.....	.....	.....	.....	3.95	4.15	.....	.45	.20	.65	.....	.....
.....	1.70	.....	3.30	6.45	4.05	1.10	.50	.....	.....	.....	.....
.....	.....	.....	3.23	6.50	.....	1.03	.50	.20	.....	.....	.....
.....	.....	.....	3.05	5.65	3.93	1.00	.40	.25	.....	.....	.....
.....	.....	.....	2.93	5.65	3.83	.98	.....	.38	.....	.82	.95
.....	.....	.....	2.90	.....	3.73	.95	.35	.48	.....	.....	.....
.....	.....	.....	2.90	5.05	3.60	.90	.35	.58	.85	.....	.....
.....	.....	.....	.....	4.90	.....	.....	.35	.....	.....	.....	.....

ly gage height, in feet, of North Platte River at Gering, Nebraska, for 1898.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	1.10	1.70	2.50	1.80	0.90	0.70	0.70
2	1.10	1.60	2.40	1.70	.90	.70	.70
3	1.10	1.70	2.40	1.60	.90	.70	.70
4	1.10	1.80	2.30	1.50	.80	.70	.70
5	1.10	1.90	2.30	1.45	.80	.60	.70
6	1.20	1.80	2.20	1.50	.80	.60	.75
7	1.20	1.70	2.20	1.40	.90	.70	.75
8	1.20	1.70	2.20	1.30	.80	.70	.75
9	1.20	1.70	2.20	1.30	.80	.80	.75
10	1.20	1.70	2.10	1.30	.80	.70	.75
11	1.20	1.60	2.10	1.30	.80	.70	.80
12	1.20	1.60	2.10	1.30	.70	.70	.80
13	1.30	1.50	2.00	1.30	.70	.70	.80
14	1.30	1.50	2.10	1.40	.70	.70	.80
15	1.30	1.50	2.10	1.30	.70	.70	.80
16	1.30	1.60	2.35	1.30	.70	.70	.80
17	1.40	1.70	2.40	1.30	.80	.70	.90
18	1.40	1.80	2.40	1.30	.80	.70	.90
19	1.40	1.90	2.30	1.30	.80	.70	.90
20	1.50	1.90	2.30	1.30	.70	.70	.90
21	1.70	2.00	2.20	1.20	.80	.70	.90
22	1.80	2.00	2.10	1.10	.80	.70	.90
23	1.80	2.10	2.10	1.10	.80	.70	.90
24	1.80	2.10	2.10	1.10	.80	.70	.90
25	1.80	2.00	2.10	1.10	.70	.70	.95
26	1.80	1.90	2.00	1.10	.70	.70	.95
27	1.80	3.00	2.00	1.00	.70	.70	.90
28	1.90	2.90	2.00	1.00	.70	.70	.90
29	1.90	3.00	1.90	1.00	.70	.70	.90
30	1.90	2.80	1.80	1.00	.70	.70	.90
31	.....	2.70	.....	.95	.70	.....	.90

Daily gage height, in feet, of North Platte River at Camp Clarke, Nebraska, for 1898.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	2.27	2.91	3.89	3.20	2.33	1.65	1.72
2	2.27	2.84	3.86	3.05	2.32	1.65	1.80
3	2.37	2.91	3.69	2.98	2.30	1.60	1.80
4	2.44	3.07	3.60	2.95	2.23	1.60	1.81
5	2.45	3.12	3.59	2.95	1.98	1.62	1.80
6	2.35	3.17	3.49	2.86	2.30	1.62	1.80
7	2.37	3.17	3.47	2.75	2.31	1.65	1.81
8	2.35	3.05	3.47	2.72	1.90	1.65	1.81
9	2.39	3.02	3.34	2.68	1.95	1.65	1.83
10	2.40	3.00	3.50	2.65	1.90	1.87	1.87
11	2.42	3.02	3.49	2.60	1.86	1.81	1.8
12	2.49	2.93	3.45	2.70	1.81	1.80	1.8
13	2.38	3.02	3.45	2.55	1.80	1.80	1.87
14	2.40	3.04	3.44	2.50	1.78	1.81	1.8
15	2.42	2.88	3.54	2.50	1.75	1.80	1.8
16	2.50	2.90	3.56	2.50	1.80	1.80	1.8
17	2.44	2.92	3.60	2.50	1.85	1.80	1.
18	2.55	2.92	3.65	2.50	1.86	1.80	1.
19	2.65	2.96	3.55	2.55	1.85	1.75	1.
20	2.72	3.17	3.56	2.55	1.80	1.67	1.
21	2.85	3.34	4.59	2.50	1.76	1.70	2
22	2.87	3.38	3.57	2.48	1.78	1.70	2
23	3.00	3.45	3.60	2.52	1.78	1.68	2
24	3.06	2.93	3.59	2.47	1.75	1.65	[illegible]
25	2.97	3.40	3.55	2.46	1.75	1.72	[illegible]
26	2.97	3.44	3.47	2.45	1.72	1.73	
27	2.97	4.10	3.40	2.35	1.60	1.73	
28	2.87	4.40	3.34	2.33	1.68	1.79	
29	2.93	4.35	3.29	2.33	1.68	1.65	
30	2.96	4.11	3.25	2.35	1.68	1.65	
31	.....	3.94	.....	2.32	1.66	.....	

Discontinued October 31, 1898.

feet, of North Platte River at North Platte, Nebraska, for 1898.

Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
2.40	2.40	2.55	3.75	2.65	1.50	.35	1.20	1.70	2.20
2.30	2.30	2.60	3.50	2.60	1.90	.45	1.10	1.70	2.20
2.15	2.25	2.70	3.35	2.60	1.95	.55	1.00	1.70	2.20
2.15	2.15	2.70	3.30	2.70	1.75	.55	1.10	1.70	2.30
2.10	2.30	2.70	3.25	2.55	1.45	.65	1.10	1.80	2.30
2.05	2.40	2.70	3.20	2.50	1.40	.50	1.20	1.80	2.30
2.05	2.30	2.75	3.20	2.45	1.50	.60	1.20	1.80	2.30
2.15	2.35	2.70	3.10	2.25	1.40	.75	1.20	1.70	2.30
2.25	2.25	2.70	3.10	2.20	1.30	.90	1.35	1.80	2.30
2.25	2.05	2.70	3.10	2.50	1.20	1.20	1.30	1.65	2.30
2.25	2.15	2.60	3.10	2.30	1.15	1.35	1.30	1.70	2.50
2.25	2.25	2.60	3.10	3.40	1.10	1.65	1.35	1.80	2.50
2.20	2.30	2.55	3.05	2.10	1.00	1.50	1.30	1.80	2.50
2.15	2.20	2.50	3.25	2.00	.90	1.70	1.30	1.80	2.50
2.25	2.10	2.55	3.15	1.90	.80	1.80	1.30	1.70	2.50
2.15	2.20	2.65	3.05	1.80	.80	1.70	1.30	1.85	2.50
2.20	2.00	3.10	3.00	1.85	.80	1.65	1.30	1.80	2.50
2.20	2.05	2.90	3.05	1.80	.80	1.50	1.30	1.90	2.50
2.25	2.05	2.80	3.10	1.80	.75	1.40	1.40	2.10	2.50
2.25	2.15	2.80	3.15	1.70	.60	1.30	1.50	2.00	2.50
2.30	2.15	2.90	3.10	1.70	.60	1.25	1.50	1.85	2.60
2.15	2.15	2.85	3.00	1.70	.60	1.20	1.50	1.80	2.60
2.00	2.25	2.90	3.00	1.60	1.00	1.20	1.60	1.80	2.60
2.00	2.20	2.80	3.00	1.60	1.05	1.20	1.60	1.80	2.60
1.95	2.25	2.80	3.00	1.65	.85	1.20	1.60	1.80	2.60
1.90	2.35	2.90	2.90	1.60	.75	1.20	1.65	1.80	2.60
2.05	2.55	3.10	2.90	1.60	.70	1.20	1.70	1.80	2.70
2.25	2.55	3.10	2.85	1.45	.55	1.10	1.70	2.10	2.70
2.45	2.55	3.00	2.70	1.30	.65	1.10	1.70	2.20	2.70
2.35	2.55	3.95	2.75	1.20	.55	1.15	1.70	2.20	2.70
2.30	.....	3.60	.....	1.40	.50	.....	1.70	.....	2.70

cubic feet per second, of Bear Creek at Morrison, Colorado, for 1898.

[Furnished by the Denver Union Water Company.]

	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
.....	.....	117	156	91	78	31	29
.....	.....	117	156	83	57	31	29
.....	60	117	151	83	47	31	26
.....	73	117	151	78	47	31	26
.....	78	117	151	117	47	31	26
.....	78	117	156	91	44	31	26
.....	91	130	156	91	44	31	23
.....	104	156	182	78	44	31	23
.....	117	143	182	78	44	31	23
.....	117	143	182	73	57	29	23
.....	130	143	182	70	55	29	26
.....	143	130	195	70	55	29	26
.....	143	130	208	68	52	29	26
.....	130	182	182	68	47	29	23
.....	130	156	169	68	47	29	23
.....	130	156	156	57	47	29	a 20
.....	130	156	156	52	47	26	20
.....	130	156	143	52	47	26	20
.....	130	156	143	47	44	26	20
.....	130	156	143	47	44	26	20
.....	130	156	143	47	44	29	20
.....	130	156	130	47	42	29	20
.....	117	151	130	78	42	29	20
.....	117	151	130	65	39	29	20
.....	117	151	130	65	39	29	20
.....	117	151	130	60	37	29	20
.....	117	148	130	57	31	29	20
.....	130	146	117	57	34	29	20
.....	130	146	104	52	31	29	20
.....	117	146	104	50	31	29	20
.....	117	.....	91	47	.....	29	.....

a Approximated after November 15; no reports sent in.

Daily gage height, in feet, of South Boulder Creek at Marshall, Colorado, fo

Day.	May.	June.	July.	Aug.	Sept.	Oct.	N
1	1.05	2.15	2.15	1.30	1.20	.75	
2	1.15	2.30	2.10	1.25	1.15	.70	
3	1.30	2.50	1.95	1.25	1.05	.80	
4	1.25	2.45	1.85	1.20	.95	.80	
5	1.35	2.25	1.85	1.20	.95	.85	
6	1.55	2.10	1.80	1.30	.95	.85	
7	1.70	2.15	1.80	1.25	.90	.75	
8	1.80	2.20	1.85	1.25	.90	.75	
9	2.05	2.20	1.85	1.20	.90	.80	
10	2.15	2.15	1.85	1.20	.90	.80	
11	2.20	2.25	1.90	1.20	.80	.80	
12	2.30	2.35	1.85	1.15	.90	.85	
13	2.20	2.35	2.05	1.15	.85	.90	
14	2.15	2.60	1.95	1.15	.85	.90	
15	2.15	2.55	1.80	1.15	.95	.90	
16	2.15	2.50	1.75	1.40	.95	.85	
17	2.15	2.65	1.70	.95	.90	.80	
18	2.15	2.55	1.70	.90	.80	.80	
19	2.05	2.60	1.65	1.05	.85	.85	
20	2.00	2.55	1.65	1.10	.85	.90	
21	2.00	2.55	1.60	.85	.80	.90	
22	1.85	2.45	1.60	.90	.80	1.00	
23	1.85	2.45	1.55	.85	.85	1.00	
24	2.05	2.25	1.55	.95	.85	1.00	
25	2.15	2.20	1.45	1.00	.85	1.00	
26	2.10	2.15	1.40	1.00	.85	1.00	
27	2.15	2.25	1.40	1.00	.80	.90	
28	2.25	2.15	1.35	1.00	.80	.90	
29	2.25	2.15	1.30	1.00	.75	.90	
30	2.30	2.10	1.30	.95	.75	.90	
31	2.25	.....	1.30	.95	.....	.90	.....

Daily gage height, in feet, of Boulder Creek at Boulder, Colorado, for 18

Day.	May.	June.	July.	Aug.	Sept.	Oct.	N
1	0.92	1.80	1.80	0.92	0.95	0.25	0
2	.93	1.85	1.73	.90	.98	.30	
3	.92	2.00	1.68	.92	.98	.28	
4	.90	2.03	1.60	.95	.90	.30	
5	.95	1.85	1.50	.98	.75	.30	
6	.95	1.68	1.52	1.30	.65	.50	
7	1.15	1.72	1.58	1.15	.63	.35	
8	1.40	1.85	1.52	1.03	.60	.33	
9	1.48	1.90	1.52	.93	.55	.30	
10	1.60	1.90	1.55	.83	.65	.30	
11	1.67	1.95	1.73	.78	.70	.28	
12	1.70	2.05	1.65	.73	.65	.25	1
13	1.65	2.35	1.60	.70	.62	.28	
14	1.60	2.43	1.58	.73	.60	.30	
15	1.57	2.43	1.53	.73	.55	.30	
16	1.60	2.43	1.50	.73	.53	.25	
17	1.62	2.40	1.43	.68	.50	.20	1
18	1.53	2.43	1.33	.65	.50	.23	1
19	1.42	2.43	1.35	.63	.45	.33	1
20	1.33	2.28	1.33	.63	.40	.33	1
21	1.20	2.20	1.28	.75	.48	.30	
22	1.22	2.23	1.15	.82	.45	.33	
23	1.30	2.25	1.08	.85	.40	.35	
24	1.42	2.28	1.08	.78	.33	.38	
25	1.60	2.20	1.05	.75	.30	.35	
26	1.68	2.08	1.02	.70	.28	.30	
27	1.78	1.95	1.02	.65	.28	.28	
28	1.85	1.93	.98	.63	.28	.25	
29	1.93	1.83	.95	.60	.28	.23	
30	1.83	1.83	.90	.60	.25	.22	
31	1.85	.....	.92	.78	.....	.22	.....

gage height, in feet, of St. Vrain Creek at Lyons, Colorado, for 1898.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
.....	1.98	2.90	3.10	2.15	2.30	1.80	1.90
.....	2.25	3.20	3.15	2.00	2.35	1.80	1.90
.....	1.95	3.50	3.05	2.10	2.30	1.80	1.90
.....	2.00	3.45	3.10	2.05	2.30	1.80	1.90
.....	2.05	2.95	3.15	2.45	2.25	1.80	1.90
.....	2.25	2.85	3.05	2.40	2.15	1.80	1.90
.....	2.55	3.10	3.10	2.40	2.15	1.80	1.90
.....	2.72	3.40	3.00	2.35	2.10	1.80	1.80
.....	2.92	3.45	3.10	2.30	2.10	1.80	1.80
.....	3.05	3.45	2.95	2.20	2.20	1.80	1.80
.....	3.05	3.55	3.30	2.20	2.20	1.80	1.80
.....	3.15	3.60	3.30	2.25	2.20	1.80	1.80
.....	3.00	3.75	3.00	2.20	2.20	1.80	1.80
.....	2.90	3.90	2.95	2.30	2.10	1.80	1.80
.....	2.95	3.90	2.85	2.25	2.10	1.80	1.80
.....	2.90	3.85	2.80	2.20	2.10	1.80	1.80
.....	2.95	4.00	2.75	2.35	2.00	1.90	1.90
.....	2.70	3.85	2.65	2.25	2.00	1.90	1.90
.....	2.70	3.85	2.55	2.30	2.00	1.90	1.90
.....	2.55	3.90	2.45	2.30	2.00	1.90	1.80
.....	2.50	3.90	2.45	2.30	2.00	1.90	1.70
.....	2.50	3.90	2.35	2.25	2.00	1.90	1.70
.....	2.45	3.80	2.45	2.30	1.90	1.80	1.70
.....	2.55	3.95	2.50	2.30	1.90	1.80	1.65
.....	2.75	3.70	2.55	2.30	1.80	1.80	1.60
.....	2.90	3.60	2.45	2.25	1.80	1.80	1.60
.....	2.70	3.30	2.45	2.25	1.80	1.85	1.60
.....	3.10	3.15	2.15	2.20	1.90	1.90	1.60
.....	3.05	3.15	2.10	2.20	1.90	1.90	1.70
.....	2.85	3.10	2.15	2.20	1.90	1.90	1.70
.....	3.00	.....	2.20	2.20	.....	1.90	.....

ge height, in feet, of Big Thompson Creek at Arkins, Colorado, for 1898.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
.....	0.45	1.30	1.40	1.00	0.75	0.30	0.10
.....	.35	1.55	1.35	.75	.75	.20	.10
.....	.30	1.60	1.25	.80	.75	.30	.10
.....	.35	1.60	1.20	.70	.50	.35	.20
.....	.25	1.40	1.05	.65	.50	.25	.15
.....	.35	1.35	1.05	.80	.50	.30	.15
.....	.45	1.50	1.20	.85	.55	.30	.35
.....	.50	1.55	1.20	.85	.55	.35	.25
.....	.75	1.60	1.20	.80	.50	.30	.10
.....	.95	1.55	1.25	.70	.50	.30	.10
.....	1.15	1.60	1.25	.60	.50	.30	.10
.....	1.10	.70	1.80	.60	.50	.30	.10
.....	1.10	.85	1.60	.65	.50	.25	.10
.....	1.10	.95	1.50	.65	.65	.25	.10
.....	1.10	1.20	1.40	.60	.60	.25	.10
.....	1.20	1.20	1.40	.60	.30	.20	.10
.....	1.20	1.25	1.35	.65	.30	.25	.10
.....	1.10	1.40	1.30	.70	.25	.30	.10
.....	.85	1.95	1.20	.60	.25	.20	.10
.....	.85	1.75	1.05	.60	.25	.25	.10
.....	.75	1.65	1.00	.60	.20	.25	.10
.....	.70	1.80	.90	.65	.25	.15	.10
.....	.85	1.95	.90	.60	.20	.20	.10
.....	.95	2.00	.90	.65	.20	.10	.15
.....	1.20	1.85	.90	.60	.25	.10	.20
.....	1.20	1.60	.85	.60	.20	.15	.30
.....	1.25	1.45	.90	.60	.20	.25	.30
.....	1.30	1.35	.80	.50	.20	.10	.30
.....	1.40	1.35	.75	.55	.25	.10	.35
.....	1.35	1.35	.70	.50	.25	.10	.35
.....	1.35	.....	.80	.50	.....	.10	.....

Daily gage height, in feet, of South Platte River at Fifteenth Street Bridge, Denver, Colorado, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	5.45	5.40	5.10	4.80	6.00	7.05	5.30	5.40	5.35	5.30	5.25
2	5.40	5.30	5.05	4.80	6.20	7.00	5.55	5.35	5.40	5.20	5.30
3	5.35	5.40	5.00	4.85	6.30	7.25	5.60	5.40	5.40	5.15	5.30
4	5.30	5.50	4.95	5.05	6.35	7.45	5.70	5.30	5.35	5.25	5.25
5	5.40	5.40	5.00	5.25	6.45	7.35	5.85	5.50	5.25	5.35	5.30
6	5.60	5.20	5.05	5.40	6.75	7.35	6.05	6.20	5.40	5.25	5.30
7	5.60	5.10	5.15	5.35	6.80	7.65	6.25	6.40	5.30	5.15	5.30
8	5.70	5.20	5.20	5.40	7.35	7.60	6.30	6.30	5.20	5.10	5.25
9	5.55	5.20	5.25	5.45	7.65	7.55	6.60	6.30	5.25	5.05	5.30
10	5.50	5.10	5.30	5.50	7.55	7.50	6.35	6.20	5.30	5.00	5.20
11	5.45	5.20	5.15	5.55	7.45	7.55	6.50	6.00	5.25	4.95	5.10
12	5.40	5.30	5.10	6.30	7.40	7.60	6.45	5.70	5.20	4.90	5.20
13	5.35	5.30	4.95	6.00	7.25	7.55	7.15	5.80	5.65	4.95	4.95
14	5.30	5.35	5.05	5.90	7.10	7.50	7.35	5.70	5.45	4.90	4.90
15	5.25	5.40	5.20	6.15	7.05	7.45	7.25	5.60	5.30	4.95	4.95
16	5.25	5.35	5.35	6.20	6.95	7.45	6.95	5.55	5.30	5.05	5.05
17	5.25	5.25	5.30	6.10	6.80	7.40	6.75	5.65	5.35	5.45	5.45
18	5.20	5.10	5.25	6.20	6.80	7.35	6.55	5.55	5.40	5.50	5.50
19	5.10	5.00	5.20	6.15	7.00	7.25	6.50	5.45	5.50	5.35	5.45
20	5.05	5.05	5.25	6.10	7.00	7.20	6.35	5.35	5.45	5.35	4.90
21	4.95	5.15	5.25	6.05	7.00	7.10	6.15	5.35	5.45	5.30	4.95
22	4.90	5.25	5.20	5.95	7.00	7.05	6.10	5.40	5.30	5.35	5.00
23	4.90	5.40	5.15	6.30	7.00	7.00	5.85	5.50	5.25	5.40	4.95
24	4.90	5.35	5.15	6.05	7.00	6.95	5.65	5.60	5.30	5.35	5.00
25	4.90	5.20	5.25	5.70	7.25	6.90	5.50	5.50	5.40	5.25	4.90
26	5.00	5.15	5.30	5.60	7.55	6.80	5.60	5.40	5.40	5.20	5.00
27	5.00	5.10	5.15	5.60	7.75	6.60	5.55	5.35	5.35	5.30	5.05
28	5.10	5.05	4.95	5.55	7.95	6.35	5.45	5.50	5.35	5.30	5.10
29	5.20	.....	4.80	5.55	7.40	6.10	5.40	5.40	5.40	5.30	5.20
30	5.30	.....	4.90	5.50	7.10	5.65	5.35	5.35	5.35	5.30	5.25
31	5.30	.....	4.85	.....	7.10	.....	5.40	5.40	.....	5.30	.....

Daily gage height, in feet, of South Platte River at Orchard, Colorado, for

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	4.50	4.25	3.60	3.70	2.10	4.00	2.40	2.20	2.20	2.40	2.90
2	4.45	4.20	3.60	3.65	2.20	3.90	2.40	2.20	2.20	2.40	2.90
3	4.40	4.20	3.60	3.65	2.30	3.70	2.40	2.20	2.20	2.40	2.85
4	4.45	4.20	3.60	3.65	3.00	3.50	2.40	2.20	2.20	2.40	2.85
5	4.50	4.20	3.60	3.65	3.50	3.50	2.40	2.20	2.20	2.45	2.80
6	4.40	4.10	3.60	3.60	3.70	3.70	2.40	2.20	2.20	2.45	2.80
7	4.50	4.05	3.60	3.60	4.00	3.50	2.40	2.20	2.20	2.50	2.80
8	4.50	4.10	3.60	3.65	3.70	3.30	2.40	2.20	2.20	2.50	2.85
9	4.50	4.05	3.60	3.65	3.90	3.40	2.20	2.20	2.20	2.50	2.85
10	4.40	4.00	3.60	3.60	4.00	3.50	2.20	2.20	2.20	2.50	2.90
11	4.30	3.95	3.60	3.60	4.30	3.50	2.30	2.20	2.25	2.60	3.10
12	4.20	3.90	3.60	3.60	4.20	3.40	2.70	2.20	2.30	2.60	3.00
13	4.10	3.90	3.60	3.60	4.25	3.30	3.00	2.20	2.40	2.60	3.00
14	4.05	3.80	3.60	3.60	4.30	3.30	3.20	2.20	2.40	2.60	3.10
15	4.00	3.85	3.60	3.60	4.30	3.40	3.30	2.20	2.40	2.60	3.10
16	4.00	3.90	3.60	3.60	4.25	3.30	3.20	2.20	2.35	2.60	3.20
17	4.00	3.85	3.60	3.60	4.20	3.40	3.00	2.20	2.35	2.60	3.20
18	4.20	3.80	3.60	3.55	4.10	3.30	2.80	2.20	2.30	2.60	3.10
19	4.30	3.85	3.60	3.80	4.00	3.00	2.70	2.20	2.30	2.60	3.20
20	4.20	3.70	3.60	3.00	4.00	3.00	2.60	2.20	2.30	2.65	3.20
21	4.10	3.70	3.65	2.90	4.00	3.00	2.50	2.20	2.30	2.65	3.30
22	4.00	3.70	3.70	2.90	3.90	2.80	2.20	2.20	2.30	2.70	3.30
23	4.00	3.70	3.75	2.90	3.80	2.60	2.20	2.20	2.30	2.70	3.30
24	3.85	3.70	3.75	2.20	3.80	2.60	2.20	2.20	2.30	2.75	3.50
25	3.70	3.70	3.80	2.25	3.80	2.60	2.20	2.20	2.30	2.80	3.70
26	3.65	3.70	3.80	2.10	3.80	2.60	2.20	2.20	2.30	2.80	3.80
27	3.60	3.60	3.80	2.10	4.40	2.60	2.20	2.20	2.30	2.85	4.00
28	3.80	3.55	3.80	2.10	4.30	2.60	2.20	2.20	2.30	2.90	4.00
29	4.00	.....	3.75	2.10	4.60	2.00	2.20	2.20	2.35	3.00	4.00
30	4.20	.....	3.75	2.10	4.50	2.00	2.20	2.20	2.35	2.95	4.50
31	4.30	.....	3.70	.....	4.20	.....	2.20	2.20	.....	2.95	.....

gage height, in feet, of Loup River at Columbus, Nebraska, for 1898.

	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
.....	4.51	4.78	5.00	4.64	4.20	4.37	4.56	4.90
.....	4.77	4.77	4.95	4.64	4.24	4.34	4.58	4.85
.....	4.75	4.86	5.02	4.60	4.28	4.30	4.59	4.80
.....	4.77	5.07	5.14	4.62	4.63	4.31	4.66	4.75
.....	4.79	5.33	5.66	4.83	4.95	4.30	4.63	4.75
.....	4.82	5.28	5.95	4.88	5.24	4.30	4.64	4.80
.....	4.86	5.25	5.68	4.83	5.16	4.30	4.67	4.80
.....	4.81	5.22	5.63	4.83	4.97	4.32	4.67	4.85
.....	4.76	5.18	5.56	4.74	4.85	4.31	4.72	4.90
.....	4.80	5.16	5.46	4.66	4.77	4.36	4.74	4.90
.....	4.79	5.19	5.35	4.68	4.68	4.42	4.84	4.94
.....	4.86	5.19	5.26	4.65	4.64	4.48	4.97	4.90
.....	4.83	5.16	5.32	4.63	4.61	4.82	4.90	.....
.....	5.06	5.07	5.36	4.67	4.58	5.03	4.82	.....
.....	5.02	4.91	5.42	4.66	4.57	4.93	4.78	.....
.....	4.93	4.95	5.36	4.65	4.59	4.80	4.76	.....
.....	4.83	4.96	5.35	4.62	4.67	4.85	4.76	.....
.....	4.77	5.15	5.30	4.54	4.83	4.81	4.77	.....
.....	4.86	5.19	5.30	4.49	4.78	4.80	4.86	.....
.....	4.93	5.18	5.33	4.44	4.66	4.73	4.92	.....
.....	4.87	5.41	5.40	4.43	4.63	4.65	4.86	.....
.....	4.75	5.44	5.50	4.41	4.65	4.49	4.82	.....
.....	4.71	5.48	5.39	4.45	4.63	4.41	4.80	.....
.....	4.73	5.68	5.00	4.35	4.62	4.50	4.85	.....
.....	4.77	5.40	4.77	4.31	4.62	4.57	4.90	.....
.....	4.85	5.64	4.71	4.30	4.63	4.58	4.80	.....
.....	4.83	5.46	4.68	4.30	4.63	4.57	4.90	.....
.....	4.83	5.34	4.67	4.28	4.56	4.56	4.90	.....
.....	4.87	5.11	4.65	4.26	4.45	4.56	4.85	.....
.....	4.81	5.10	4.66	4.26	4.41	4.56	4.80	.....
.....	.....	4.98	.....	4.22	4.39	.....	4.95	.....

gage height, in feet, of Platte River at Columbus, Nebraska, for 1898.

May.	June.	July.	Day.	Apr.	May.	June.	July.	Day.	Apr.	May.	June.	July.
2.50	3.90	3.60	12...	.....	3.45	4.35	2.80	23...	2.25	3.98	3.50	(a)
2.80	5.10	3.40	13...	.....	3.34	4.28	2.60	24...	2.10	4.12	3.60	(a)
3.22	4.50	3.42	14...	.....	3.27	4.22	2.55	25...	2.00	3.98	3.60	(a)
3.40	5.00	3.45	15...	.....	3.24	4.15	2.50	26...	2.06	3.85	3.50	(a)
3.70	4.90	3.40	16...	.....	3.27	4.35	2.55	27...	1.97	4.04	3.40	(a)
3.75	4.72	3.38	17...	2.36	3.34	4.20	2.50	28...	1.95	3.93	3.42	(a)
3.80	4.85	3.20	18...	2.42	3.50	4.05	2.45	29...	1.95	3.75	3.45	(a)
3.70	4.65	3.15	19...	2.55	3.28	3.96	2.20	30...	2.60	3.85	3.50	(a)
3.56	4.45	3.20	20...	2.60	3.90	3.78	2.00	31...	.....	4.03	.....	(a)
3.55	4.52	3.00	21...	2.65	4.30	3.56	(a)					
3.35	4.48	2.90	22...	2.40	4.10	3.58	(a)					

a River dry.

gage height, in feet, of Elkhorn River at Norfolk, Nebraska, for 1898.

	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
.....	1.66	1.53	2.64	1.75	1.03	1.08	.93	1.37
.....	1.65	1.53	2.53	1.73	1.03	1.00	.99	1.35
.....	1.65	1.66	2.40	1.53	1.02	1.00	1.03	1.35
.....	1.64	1.67	2.77	1.66	1.02	1.00	1.03	1.35
.....	1.63	1.76	4.44	1.67	1.01	.98	1.04	1.35
.....	1.63	1.82	4.70	1.66	1.02	.98	1.02	1.35
.....	1.57	1.93	3.62	1.67	1.03	.97	1.02	1.35
.....	1.58	1.87	3.36	1.71	1.33	.98	1.02	1.36
.....	1.56	1.95	3.28	1.68	1.36	1.01	1.03	1.33
.....	1.55	1.97	3.78	1.65	1.56	1.05	1.04	1.33
.....	1.55	1.90	3.47	1.63	1.60	1.03	1.15	1.34
.....	1.59	1.84	3.15	1.57	1.70	1.17	1.17	1.34
.....	1.61	1.82	3.00	1.55	1.56	1.18	1.18	1.34
.....	1.61	1.87	2.92	1.49	1.56	1.14	1.18	1.39
.....	1.60	1.96	2.77	1.45	1.49	1.15	1.19	1.42
.....	1.60	1.85	2.67	1.48	1.44	1.13	1.13	1.42
.....	1.59	1.86	2.62	1.28	1.42	1.13	1.23	1.43
.....	1.61	2.06	2.58	1.26	1.37	1.13	1.28	1.41
.....	1.63	2.08	2.52	1.26	1.39	1.19	1.30	1.43
.....	1.65	2.68	2.54	1.18	1.42	1.07	1.33	1.50
.....	1.64	2.69	2.49	1.10	1.37	1.03	1.30	1.65
.....	1.60	2.65	2.34	1.13	1.21	.96	1.32	1.72
.....	1.60	2.56	2.25	1.10	1.22	.98	1.33	1.76
.....	1.60	2.63	2.15	1.10	1.26	1.02	1.37	1.80
.....	1.57	3.23	2.13	1.13	1.27	1.03	1.36	1.80
.....	1.53	3.13	2.10	1.03	1.24	1.01	1.36	1.80
.....	1.52	3.10	2.04	1.01	1.24	1.12	1.39	1.87
.....	1.49	3.02	1.96	1.00	1.24	.97	1.38	1.87
.....	1.47	2.99	1.91	.98	1.22	.97	1.38	1.87
.....	1.52	2.89	1.85	1.03	1.18	.97	1.37	1.87
.....	.....	2.72	.....	1.07	1.15	.....	1.37	.....

List of discharge measurements, 1898.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	I ch
				Feet.	*Sec*
Apr. 30	Laramie River	Woods Landing, Wyo.	C. T. Johnston	1.40	
May 22	do	do	do	2.00	
June 4 *a*	do	do	do	2.30	
Do. *b*	do	do	do	2.40	
June 5	do	do	do	2.10	
Apr. 23	do	Uva, Wyo	do	1.10	
May 12	do	do	do	1.40	
May 27	do	do	do	3.50	
June 8	do	do	do	3.20	
June 22	do	do	do	2.95	
Apr. 21	North Platte River	Orin Junction, Wyo.	do	3.45	
May 10	do	do	do	3.00	
May 26	do	do	do	6.30	1
June 8	do	do	do	4.50	
June 21	do	do	do	4.50	
July 2	do	do	do	3.10	
May 13	do	Gering, Nebr	Robt. H. Willis	1.50	
June 6	do	do	do	2.20	
June 22	do	do	do	2.20	
July 2	do	do	do	1.70	
May 6	do	Camp Clarke, Nebr.	do	3.17	
May 24	do	do	do	3.45	
June 8	do	do	do	3.54	
June 17	do	do	do	3.61	
June 29	do	do	do	3.30	
Sept. 28	do	do	do	1.79	
Apr. 15	do	North Platte, Nebr.	Charles P. Ross	2.10	
May 2	do	do	do	2.60	
May 14	do	do	do	2.50	
May 23	do	do	do	2.90	
May 31	do	do	do	3.60	1
June 4	do	do	do	3.25	
June 23	do	do	do	3.00	
July 22	do	do	do	1.70	
July 30	do	do	do	1.20	
Aug. 15	do	do	do	.80	
Aug. 23	do	do	do	1.00	
Sept. 9	do	do	do	.90	
Sept. 27	do	do	do	1.20	
Oct. 11	do	do	do	1.30	
Oct. 26	do	do	do	1.65	
Nov. 7	do	do	do	1.80	
Apr. 22	Bear Creek	Morrison, Colo	A. L. Fellows	2.26	
Apr. 23	South Boulder Creek.	Marshall, Colo	do	1.35	
May 29	do	do	do	2.20	
July 11	do	do	do	1.70	
Aug. 6	do	do	do	1.15	
Oct. 10	do	do	do	.35	
Apr. 17	Boulder Creek	Boulder, Colo	do	[illegible]	
May 28	do	do	do	1.85	
July 16	do	do	J. E. Field	[illegible]	
Aug. 8	do	do	A. L. Fellows	[illegible]	
Oct. 11	do	do	do	[illegible]	
May 27	St. Vrain Creek	Lyons, Colo	do	[illegible]	
July 12	do	do	do	[illegible]	
Aug. 5	do	do	do	[illegible]	
Oct. 12	do	do	do	[illegible]	
May 26	Big Thompson Creek.	Arkins, Colo	do	1.25	
July 13	do	do	do	[illegible]	
Aug. 4	do	do	do	[illegible]	
Oct. 14	do	do	do	[illegible]	
Apr. 21	South Platte River	Denver, Colo	do	[illegible]	
July 6	do	do	do	[illegible]	
Sept. 2	do	do	do	[illegible]	
Oct. 4	do	do	do	[illegible]	
Oct. 29	do	do	F. A. [illegible]	[illegible]	
Apr. 24	do	Cheyenne, Colo	A. L. Fellows	[illegible]	
May 8	do	do	do	[illegible]	
July 4	do	do	do	[illegible]	
Aug. 4	do	do	do	[illegible]	
Nov. 5	do	do	F. A. [illegible]	[illegible]	
Nov. 17	do	do	do	[illegible]	

a 8 a. m.

b South Boulder and [illegible] Creek [illegible] manity Ditch. Gage height 2.0 feet. Discharge [illegible]

List of discharge measurements, 1898—Continued.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
				Feet.	*Sec.-feet.*
Apr. 17	Loup River	Columbus, Nebr.	Glenn E. Smith	4.80	2,730
May 8	do	do	do	5.15	3,231
May 19	do	do	do	5.20	3,542
May 29	do	do	do	5.05	3,337
June 8	do	do	do	5.50	5,181
June 19	do	do	O. V. P. Stout	5.03	3,284
July 10	do	do	Glenn E. Smith	4.60	1,900
July 22	do	do	do	4.40	1,691
July 31	do	do	do	4.15	1,560
Aug. 21	do	do	Adna Dobson	4.65	2,542
Sept. 4	do	do	do	4.20	1,389
Sept. 17	do	do	do	4.81	2,448
Sept. 25	do	do	do	4.59	2,117
Oct. 16	do	do	do	4.75	2,381
Oct. 30	do	do	do	4.80	2,519
Nov. 20	do	do	Glenn E. Smith	4.90	2,862
Apr. 17	Platte River	do	do	2.37	1,994
May 9	do	do	do	3.65	5,612
May 19	do	do	do	3.33	3,619
May 29	do	do	do	3.82	7,104
June 8	do	do	do	4.69	16,543
June 19	do	do	O. V. P. Stout	3.95	9,123
July 10	do	do	Glenn E. Smith	3.00	3,006
July 29	do	do	do	(a)	285
July 31	do	do	do	(a)	45
Aug. 21	Main channel		Adna Dobson		(b)
	Middle channel		do		½
	South channel		do		2
Sept. 4	Main channel		do		(b)
	Middle channel		do		(b)
	South channel		do		2
Sept. 18	Main channel		do		(b)
	Middle channel		do		6
	South channel		do		4
Oct. 16	Main channel		do		(b)
	Middle channel		do		6
	South channel		do		8
Oct. 30	Main channel		do		(b)
	Middle channel		do		5
	South channel		do		8
Nov. 11	Main channel		Glenn E. Smith		(b)
	Middle channel		do		6
	South channel		do		10
Nov. 20	Main channel		do		(b)
	Middle channel		do		10
	South channel		do		15
Apr. 24	Elkhorn River	Norfolk, Nebr.	do	1.60	451
May 12	do	do	do	1.84	493
May 23	do	do	do	2.56	782
June 10	do	do	do	2.86	1,319
June 20	do	do	O. V. P. Stout	2.46	760
July 28	do	do	Glenn E. Smith	1.05	228
Aug. 20	do	do	do	1.28	288
Sept. 10	do	do	do	1.00	175
Sept. 27	do	do	do	1.00	205
Oct. 22	do	do	do	1.34	256
Oct. 28	do	do	do	1.40	287
Nov. 16	do	do	do	1.40	330
Dec. 16	do	do	do	Frozen	216
Dec. 27	do	do	do	do	217
May 10	North Fork of Elkhorn River.	do	do		109
July 28	do	do	do		63
Aug. 20	do	do	do		87
Sept. 10	do	do	do		97
Sept. 27	do	do	do		79
Oct. 28	do	do	do		98
Nov. 16	do	do	do		104
Dec. 27	do	do	do		106

a Gage out of water. b Dry.

List of miscellaneous discharge measurements, 1898.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Dis-charge
				Feet.	*Sec.-fe*
Apr. 23	Beaver River	Albion, Nebr	Glenn E. Smith		8
Apr. 26	Niobrara River	Lavaca, Nebr	do		21
Apr. 27	White River	Crawford, Nebr	do		1
Do.	do	do	do		1
Do.	Soldier Creek	do	do		
Do.	Fort Ditch	Fort Robinson, Nebr	do		
Apr. 28	Middle Loup River	Dunning, Nebr	do		41
Do.	do	Seneca, Nebr	do		2
Do.	Dismal River	Dunning, Nebr	do		3
May 13	Minnechadusa River	Valentine, Nebr	do		2
May 24	do	do	do		8
May 26	Elkhorn River	Arlington, Nebr	do		1,8
June 11	do	O'Neill, Nebr	do		2
June 12	Minnechadusa River	Valentine, Nebr	do		3
July 7	Frenchman River	Palisade, Nebr	do		1
Do.	Stinking Water River	do	do		1
July 27	Minnechadusa River	Valentine, Nebr	do		
Aug. 21	Long Pine River	Long Pine, Nebr	do		
Do.	Minnechadusa River	Valentine, Nebr	do		
Sept. 7	do	do	do		
Sept. 8	Plum Creek	Johnstown, Nebr	do		
Sept. 9	Elk Creek	Bassett, Nebr	do		
Sept. 10	Bone Creek	Long Pine, Nebr	do		
Sept. 26	Minnechadusa River	Valentine, Nebr	do		
Oct. 15	do	do	do		
Oct. 29	do	do	do		
Oct. 30	Niobrara River	Lavaca, Nebr	do		2
Oct. 31	White River	Crawford, Nebr	do		
Do.	do	6 miles west of Crawford, Nebr.	do		
Do.	Soldier Creek	Fort Robinson, Nebr	do		
Do.	Niobrara River	Marsoland, Nebr	do		
Nov. 1	Dismal River	Dunning, Nebr	do		3
Do.	Middle Loup River	do	do		4
Do.	do	Seneca, Nebr	do		1
Nov. 2	Platte River	Grand Island, Nebr	do		(a)
Nov. 17	Minnechadusa River	Valentine, Nebr	do		
Dec. 15	Elkhorn River	Arlington, Nebr	do		4
Dec. 17	Minnechadusa River	Valentine, Nebr	do		
Dec. 28	do	do	do		

a Dry.

NOTE.—Additional measurements will be given in the Twentieth Annual Report, Part

Rating tables.

Woods Landing.		Uva.		Orin.		Gering.		Camp Clarke.		North Pla	
Gage height.	Dis-charge.	Gage height.	Dis-charge.	Gage height.	Dis-charge.	Gage height.	Dis-charge.	Gage height.	Dis-charge.	Gage height.	ch
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Se*
0.4	45	0.5	5	0.0	300	0.6	50	1.6	60	0.3	
.5	50	.6	10	.2	370	.7	100	1.7	105	.4	
.6	60	.7	15	.4	450	.8	200	1.8	150	.5	
.7	70	.8	21	.6	550	.9	350	1.9	230	.6	
.8	85	.9	30	.8	650	1.0	650	2.0	325	.7	
.9	100	1.0	40	1.0	750	1.1	1,000	2.1	425	.8	
1.0	125	1.1	50	1.2	850	1.2	1,450	2.2	570	.9	
1.1	155	1.2	62	1.4	950	1.3	2,000	2.3	725	1.0	
1.2	200	1.3	80	1.6	1,050	1.4	2,700	2.4	950	1.2	
1.3	245	1.4	100	1.8	1,150	1.5	3,400	2.5	1,200	1.4	
1.4	290	1.5	120	2.0	1,300	1.6	4,100	2.6	1,500	1.6	
1.5	350	1.6	140	2.2	1,450	1.7	4,900	2.7	1,800	1.8	
1.6	410	1.7	160	2.4	1,675	1.8	5,700	2.8	2,200	2.0	
1.7	475	1.8	190	2.6	1,930	1.9	6,500	2.9	2,600	2.2	
1.8	550	1.9	220	2.8	2,220	2.0	7,400	3.0	3,050	2.4	
1.9	630	2.0	260	3.0	2,550	2.1	8,300	3.1	3,600	2.6	
2.0	710	2.2	340	3.2	2,935	2.2	9,200	3.2	4,200	2.8	
2.1	825	2.4	425	3.4	3,390	2.3	10,100	3.3	4,900	3.0	
2.2	940	2.6	520	3.6	3,895	2.4	11,100	3.4	5,900	3.2	
2.3	1,055	2.8	620	3.8	4,465	2.5	12,150	3.5	6,900	3.4	
2.4	1,170	3.0	720	4.0	5,096	2.6	13,300	3.6	7,900	3.6	1
2.5	1,285	3.2	820	4.5	7,000	2.7	14,500	3.7	8,900	3.8	1
2.6	1,400	3.4	920	5.0	9,200	2.8	15,700	3.8	9,900	4.0	1
2.7	1,515	3.6	1,040	5.5	11,400	2.9	17,100	3.9	10,900		
2.8	1,630	3.8	1,220	6.0	13,600	3.0	18,500	4.0	12,000		
2.9	1,745	4.0	1,400	6.5	15,870			4.1	13,300		
3.0	1,860	4.5	1,850	7.0	18,220			4.2	14,600		
3.5	2,435	5.0	2,300					4.3	15,900		
4.0	3,300	5.5	2,750					4.4	17,200		

Rating tables—Continued.

Marshall.		Boulder.		Lyons.		Arkins.		Denver.		Orchard.[a]	
Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
0.5	1	0.2	3	2.0	40	0.2	8	4.8	50	2.0	0
.6	4	.3	7	2.1	64	.3	18	4.9	69	2.1	10
.7	9	.4	13	2.2	89	.4	30	5.0	90	2.2	40
.8	15	.5	20	2.3	115	.5	45	5.1	113	2.3	75
.9	22	.6	29	2.4	141	.6	63	5.2	139	2.4	113
1.0	31	.7	41	2.5	166	.7	85	5.3	168	2.5	153
1.1	41	.8	56	2.6	192	.8	111	5.4	201	2.6	195
1.2	52	.9	75	2.7	218	.9	142	5.5	239	2.7	240
1.3	64	1.0	98	2.8	243	1.0	177	5.6	283	2.8	298
1.4	78	1.1	124	2.9	269	1.1	215	5.7	334	2.9	346
1.5	93	1.2	153	3.0	295	1.2	256	5.8	392	3.0	408
1.6	110	1.3	184	3.1	320	1.3	297	5.9	456	3.1	482
1.7	130	1.4	216	3.2	346	1.4	341	6.0	525	3.2	593
1.8	152	1.5	250	3.3	372	1.5	385	6.1	599	3.3	781
1.9	176	1.6	283	3.4	397	1.6	429	6.2	677	3.4	968
2.0	201	1.7	316	3.5	423	1.7	473	6.3	759	3.5	1,155
2.1	226	1.8	350	3.6	449	1.8	517	6.4	844	3.6	1,342
2.2	251	1.9	383	3.7	474	1.9	561	6.5	932	3.7	1,529
2.3	276	2.0	416	3.8	500	2.0	605	6.6	1,022	3.8	1,716
2.4	301	2.2	483	3.9	526	.....	.....	6.7	1,114	3.9	1,903
2.5	326	2.4	550	4.0	551	.....	.....	6.8	1,207	4.0	2,090
2.6	352	2.6	616	4.1	577	.....	.....	6.9	1,301	4.1	2,277
2.7	377	2.8	683	.....	.....	.....	.....	7.0	1,396	4.2	2,464
2.8	402	3.0	750	.....	.....	.....	.....	7.1	1,492	4.3	2,651
2.9	427	3.2	816	.....	.....	.....	.....	7.2	1,588	4.4	3,838
3.0	452	3.4	883	.....	.....	.....	.....	7.3	1,684	4.5	3,026
.....	.....	3.6	950	.....	.....	.....	.....	7.4	1,780	4.6	3,214
.....	.....	3.8	1,016	.....	.....	.....	.....	7.5	1,876	.....	.....
.....	.....	4.0	1,083	.....	.....	.....	.....	7.6	1,972	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	7.7	2,068	.....	.....

[a] Applicable from April 24 to December 31, 1898.

KANSAS RIVER DRAINAGE.

DESCRIPTION OF RIVER STATIONS.

Superior station on Republican River.—Described on page 107 of Paper No. 16; results for 1897 shown on page 338 of the Nineteenth Annual Report, Part IV. The observer was Carl Schaer. The station was discontinued on December 1, 1898. Flashboards were kept on the dam from September 13 to October 12. As noted in descriptions in Paper No. 16, the gage rod was first placed just above the river highway bridge, which is itself some 75 or 100 yards above the dam which diverts water into the mill race. This gage remained in place during the season of 1898, and was read by the hydrographer in connection with measurements of discharge, the reading being noted under the head of "river gage." At the beginning of the season of 1898 two other gages were installed at this station, one being placed in the river a few feet upstream from the crest of the dam, and the other being placed in the mill race where it is crossed by a wagon bridge about 50 yards below the head of the race. The former of these two additional gages has been called the "dam gage," to distinguish it from the "river gage" previously noted. Its zero was placed as nearly as practicable at the height of the crest of the dam. The gage in the mill race was set so that at the time of setting its reading was 2 feet in excess of that on the "dam gage." The observer was instructed to make daily one set of observations, consisting of the following: Reading on "dam gage," reading of gage in

mill race, and length of time required for float in midstream in mill race to traverse a range of 50 feet which had been staked on the banks.

Measurements of discharge were made, as in previous years, at the highway bridge, thus determining at once the sum of the discharges over the dam and through the mill race. The discharge of the mill race was measured in order that it might be deducted from the total measured discharge of the river to give the amount passing over the dam. It was hoped that the relation between water height on "dam gage" and the amount of water passing over the dam would be stable and regular. It was also hoped that the daily observations of gage height and midstream surface velocity in the mill race would furnish data for the reliable estimation of the amount to be added to that passing over the dam in order to give the total discharge of the river. On computing the results for the season, it appears that while there is not the regularity and degree of certainty hoped for, yet the scheme, with slight modifications, is the best that can be devised for this station. The accompanying table of daily gage heights gives the reading of the gage at the dam, and the computations of discharge for 1898 are based upon the readings at this gage. The height on this gage is also given in the list of discharge measurements rather than that on the river gage.

Junction City station on Republican River.—Described on page 109 of Paper No. 16; results for 1897 given on page 339 of the Nineteenth Annual Report, Part IV.

Niles station on Solomon River.—Described on page 111 of Paper No. 16; results for 1897 given on page 342 of the Nineteenth Annual Report, Part IV.

Salina station on Saline River.—Described on page 113 of Paper No. 16; results for 1897 given on page 343 of the Nineteenth Annual Report, Part IV.

Ellsworth station on Smoky Hill River.—Described on page 114 of Paper No. 16; results for 1897 given on page 346 of the Nineteenth Annual Report, Part IV.

Manhattan station on Blue River.—Described on page 115 of Paper No. 16; results for 1897 given on page 347 of the Nineteenth Annual Report, Part IV.

Lawrence station on Kansas River.—Described on page 116 of Paper No. 16; results for 1897 given on page 349 of the Nineteenth Annual Report, Part IV. The quantity of water passing through the flume leading to the water wheels at this station is very variable. There are eight of these water wheels of several different sizes. They may all be in use at one time, causing a discharge of several hundred second-feet; or only two of them may be running, using a much smaller quantity of water. Even though this flume be carefully rated for any number of these wheels in use, it is difficult to determine which are in use each day and the number of hours they are in use. For these reasons it has been decided to establish a gage at Lecompt

out 11 miles by rail up the river, where a new carriage bridge the river will furnish a convenient place for measuring the ge.

TABLES OF DAILY GAGE HEIGHT.

ge height, in feet, of Republican River at Superior, Nebraska, for 1898 (on gage at dam). (a)

y.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
.....	.....	0.69	1.21	0.70	0.30	0.09	1.27	0.47
.....	.....	1.23	1.06	.73	.34	(b)	1.34	.49
.....	.....	.85	1.04	.68	.31	(b)	1.21	.50
.....	.....	.86	1.02	.51	.30	2.00	1.21	.54
.....	.....	.90	1.04	.61	.30	(b)	1.22	.50
.....	.....	1.00	1.19	.61	.30	.59	1.21	.59
.....	.....	1.04	1.03	.60	.24	.53	1.24	.53
.....	.....	1.14	1.44	.60	.34	.52	1.28	.52
.....	.....	1.02	1.26	.72	.26	.53	1.31	.53
.....	.....	1.16	1.27	1.24	.24	.09	1.39	.51
.....	.....	1.03	1.70	1.04	.21	1.17	1.40	.52
.....	.....	.99	1.41	.72	.17	1.35	1.45	.59
.....	.....	1.14	1.34	.74	.18	1.42	.43	.64
.....	.....	1.22	1.38	.99	.34	1.35	.41	.59
.....	.....	.93	1.38	.87	.20	1.34	.40	.60
.....	.....	.99	1.36	.74	.21	1.24	.49	.60
.....	.....	.96	1.40	.73	.21	1.25	.53	.65
.....	.....	.98	1.26	.67	.17	1.35	.43	.63
.....	.....	.95	1.47	.61	.18	1.30	.45	.63
.....	0.77	1.04	1.29	.55	.05	1.30	.43	.72
.....	.77	1.33	1.20	.51	.16	1.65	.42	(c)
.....	1.02	1.42	1.11	.60	(b)	1.59	.44	(c)
.....	1.63	1.24	1.18	.50	(b)	1.55	.54	(c)
.....	1.00	1.00	1.07	.50	.55	1.40	.44	(c)
.....	.81	.98	.99	.40	.40	1.47	.43	(c)
.....	.76	1.07	.88	.50	.31	1.35	.47	(c)
.....	.74	.99	.89	.41	.29	1.32	.39	(c)
.....	.74	1.05	.84	.40	.35	1.32	.49	(c)
.....	.68	1.50	.80	.40	.28	1.31	.47	(c)
.....	.71	1.39	.74	.32	(b)	1.29	.59	(c)
.....	.....	1.13	.....	.41	(b)	.....	.49	.....

tation discontinued December 1. *b* Water below gage. *c* Frozen.

ge height, in feet, of mill race on Republican River at Superior, for 1898.

y.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
.....	.....	2.68	3.20	2.81	2.29	0.92	3.50	2.44
.....	.....	3.57	3.07	2.61	2.34	1.53	3.40	2.52
.....	.....	2.90	3.21	2.30	2.31	1.49	3.20	2.51
.....	.....	2.95	2.95	2.22	2.28	2.70	3.20	2.53
.....	.....	2.99	3.10	2.60	2.30	(a)	3.22	2.50
.....	.....	3.03	3.24	2.60	•2.29	(a)	3.21	2.67
.....	.....	3.23	3.12	2.60	2.30	(a)	3.25	2.52
.....	.....	3.29	3.69	2.55	2.33	1.60	3.29	2.53
.....	.....	3.17	3.42	2.70	2.26	(a)	3.41	2.52
.....	.....	3.39	3.58	2.38	2.23	1.95	3.41	2.53
.....	.....	3.22	4.11	2.14	2.21	3.18	3.40	2.52
.....	.....	3.18	3.64	2.72	2.17	3.38	3.50	2.60
.....	.....	3.11	3.40	2.70	2.14	3.43	2.43	2.72
.....	.....	3.18	3.50	2.00	2.35	3.35	2.39	2.61
.....	.....	3.15	3.59	2.90	2.16	3.34	2.42	2.64
.....	.....	3.20	3.57	2.71	2.21	3.25	2.50	2.66
.....	.....	3.17	3.60	2.87	2.20	3.25	2.54	2.70
.....	.....	3.11	3.35	2.62	2.12	3.40	2.46	2.68
.....	.....	3.25	3.70	2.59	2.18	3.30	2.41	2.67
.....	2.79	3.18	3.32	2.50	2.05	3.35	2.41	2.81
.....	2.79	3.65	3.18	2.49	2.17	3.63	2.40	.....
.....	2.37	3.89	3.00	2.45	1.70	4.69	2.40	.....
.....	3.06	3.47	3.33	2.40	1.61	3.58	2.60	.....
.....	3.17	3.08	3.12	2.50	2.55	3.50	2.41	.....
.....	2.79	3.19	3.03	2.38	2.41	3.50	2.40	.....
.....	2.69	3.12	2.55	2.51	2.29	3.39	2.43	.....
.....	2.67	3.20	2.91	2.07	2.28	3.36	2.10	.....
.....	2.65	3.12	2.87	2.38	2.35	3.32	2.50	.....
.....	2.69	3.87	2.80	2.40	2.31	3.31	2.44	.....
.....	2.70	3.60	2.77	2.31	1.11	3.30	2.60	.....
.....	.....	3.29	.....	2.44	1.62	.....	2.49	.....

a Lower than gage board.

Daily gage height, in feet, of Blue River at Manhattan, Kansas, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.50	4.05	4.65	4.20	7.95	8.85	5.00	4.00	3.50	3.90	3.65	4.00
2	4.50	4.00	4.60	4.35	7.10	7.90	4.70	4.00	3.45	3.95	3.80	4.10
3	4.60	4.10	4.60	4.30	6.05	7.45	4.35	4.10	3.40	4.00	3.95	4.20
4	4.60	4.20	4.60	4.40	6.45	7.20	4.15	4.05	3.50	3.90	4.05	4.05
5	4.60	4.30	4.50	4.55	6.80	7.20	4.00	4.00	3.60	3.85	3.95	4.00
6	4.50	4.30	4.45	6.00	7.25	6.75	4.20	4.05	3.55	3.75	4.05	3.90
7	4.50	4.40	4.35	5.80	7.40	9.00	4.40	3.90	3.50	3.70	3.95	3.90
8	4.40	4.25	4.25	5.70	7.30	12.00	4.65	3.95	3.60	3.60	3.80	3.85
9	4.40	4.45	4.20	5.40	7.20	13.70	4.95	4.10	3.60	3.55	3.70	4.15
10	4.25	4.60	4.05	5.15	7.00	13.20	5.25	4.00	3.75	3.50	3.70	4.15
11	4.20	9.60	4.10	4.70	6.70	13.00	5.45	3.95	3.85	3.45	3.75	4.10
12	4.20	10.15	4.35	4.60	6.30	13.35	5.35	3.85	3.95	3.40	3.70	4.10
13	4.30	9.85	4.55	4.90	5.95	12.80	5.10	3.80	4.15	3.45	3.80	4.00
14	4.30	9.25	4.70	5.05	7.95	11.50	4.70	3.90	4.30	3.45	3.90	4.05
15	4.30	8.80	4.75	5.40	7.80	10.75	4.50	3.95	4.25	3.35	3.80	4.15
16	4.45	8.20	4.70	5.45	6.40	10.10	4.40	4.00	4.15	3.40	3.70	4.15
17	4.50	7.55	4.80	5.30	5.85	9.70	4.40	4.00	4.00	3.55	3.75	4.10
18	4.60	7.35	4.90	6.20	5.75	9.40	4.30	4.10	3.85	3.60	3.85	4.05
19	4.60	7.25	4.95	8.15	6.20	9.05	4.25	4.20	3.75	3.75	3.90	4.35
20	4.50	7.15	5.00	7.65	10.30	8.75	4.10	4.10	3.65	3.65	3.80	4.40
21	4.50	7.05	4.75	7.35	12.45	8.40	4.00	4.05	3.60	3.70	3.85	4.45
22	4.60	7.00	4.60	6.40	11.50	8.05	4.00	4.00	3.55	3.75	3.85	4.40
23	4.60	6.70	4.45	5.65	11.65	7.40	4.20	3.95	3.55	3.75	3.85	4.30
24	4.60	6.35	4.30	5.90	10.90	6.90	4.30	3.85	3.75	4.25	3.95	4.45
25	4.50	6.00	4.25	6.75	10.05	6.25	4.20	3.75	3.75	4.15	4.10	4.40
26	4.45	5.70	4.25	6.10	9.70	5.90	4.15	3.65	3.60	3.95	4.00	4.35
27	4.35	5.40	4.15	5.80	9.40	5.55	4.10	3.60	3.55	3.85	4.00	4.45
28	4.25	4.70	4.25	5.60	9.25	5.45	4.00	3.50	3.50	3.70	4.05	4.45
29	4.20	.....	4.30	5.85	9.05	5.20	4.10	3.45	3.65	3.55	4.00	4.50
30	4.15	.....	4.30	6.20	8.55	5.05	4.00	3.40	3.80	3.45	3.95	4.45
31	4.10	.....	4.30	.....	8.10	.....	4.10	3.45	.....	3.45	.....	4.50

Daily gage height, in feet, of Kansas River at Lawrence, Kansas, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	0.10	0.20	0.80	0.60	3.70	3.70	1.50	0.40	−0.40	0.00	0.10	−1.30
2	.20	− .10	.80	.60	4.90	3.60	1.40	.40	− .40	.20	− .05	−1.15
3	.10	− .40	.80	.70	4.00	2.90	1.60	.30	− .40	.00	− .10	+ .10
4	.20	.00	.70	.80	3.10	2.50	1.60	.20	+ .40	− .30	− .05	−2.00
5	.20	.00	.60	1.80	2.50	2.60	1.50	.20	.40	− .80	+ .05	−1.60
6	.20	.40	.60	1.40	2.50	2.10	1.40	.20	.40	−1.10	.15	− .20
7	.20	.60	.60	1.10	2.90	2.00	1.40	.20	.60	−1.20	.10	−1.20
8	.20	.60	.60	1.00	2.60	2.40	1.40	.20	.60	−1.00	.00	− .90
9	.40	.60	.60	1.00	2.10	5.10	1.10	.20	.80	.00	− .15	−2.25
10	.30	.60	.60	1.00	2.00	5.60	1.00	.20	1.00	.00	− .25	−1.45
11	.30	1.00	.60	1.00	1.90	5.20	1.00	.20	1.00	− .80	− .15	− .20
12	.30	1.40	.60	.80	1.70	5.20	.90	.20	1.00	− .90	− .20	− .80
13	.40	1.40	.60	1.00	1.70	4.90	.90	.20	1.00	−1.10	+ .25	−1.60
14	.40	1.40	.60	1.10	3.20	4.70	.90	.20	.90	−1.00	.15	−1.10
15	.40	2.00	.80	1.10	5.25	4.20	.90	.20	.70	−1.00	− .40	−1.10
16	.40	1.80	.70	1.00	5.10	4.40	.80	.20	.20	+ .30	− .25	−1.90
17	.40	1.70	.70	1.10	4.60	3.90	.80	.20	.10	.35	− .10	− .40
18	.40	1.40	.80	1.10	3.90	3.20	.80	.80	.20	.20	− .10	− .50
19	.40	1.40	1.00	1.00	3.40	3.70	.80	.90	.40	.15	.00	− .60
20	.40	1.40	1.20	.90	3.20	3.60	.80	.80	.40	.30	.15	− .60
21	.30	1.20	1.20	1.70	3.35	3.20	.70	.60	.25	.30	− .10	+ .90
22	.30	1.00	1.20	1.90	4.20	2.80	.60	.50	.20	.20	−2.15	1.00
23	.40	1.00	1.20	2.00	4.10	2.50	.60	.30	.05	.35	−1.00	1.00
24	.40	.90	1.10	1.80	4.00	2.30	.60	.20	.00	.25	− .90	1.30
25	.40	.80	.90	1.70	3.70	2.40	.60	.20	.20	− .30	−1.00	1.40
26	.20	.80	.80	1.50	2.90	2.30	.50	.00	.30	−1.40	−1.70	1.20
27	.20	.80	1.60	1.40	3.90	2.20	.40	.00	.35	− .30	+ .10	1.20
28	.40	.80	2.00	1.30	5.10	1.90	.40	.00	.50	− .15	− .90	1.00
29	.40	.....	1.40	1.20	4.70	1.70	.40	− .20	.35	− .10	−1.00	1.05
30	.40	.....	.90	1.80	3.80	1.60	.40	− .40	.10	+ .20	−1.10	1.00
31	.30	.....	.60	.....	3.20	.....	.60	− .40	.....	.30	.....	.70

List of discharge measurements, 1898.

Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
			Feet.	*Sec.-feet.*
Mill race, Republican River.	Superior, Nebr.	Glenn E. Smith	2.79	87
do	do	do	3.39	65
do	do	do	3.12	50
do	do	do	3.00	52
do	do	do	2.91	52
do	do	do	2.50	85
do	do	do	2.29	56
do	do	do	2.35	11
do	do	do	3.40	68
do	do	do	3.40	8
do	do	do	2.50	86
Republican River	do	do	.79	626
do	do	do	1.16	1,337
do	do	do	1.05	1,030
do	do	do	1.40	1,573
do	do	O. V. P. Stout	.89	679
do	do	Glenn E. Smith	.60	416
do	do	do	.30	119
do	do	Adna Dobson	.15	76
do	do	Glenn E. Smith	1.40	252
do	do	Adna Dobson	1.18	143
do	do	Glenn E. Smith	.50	380
do	Junction City, Kans.	W. G. Russell	4.80	1,409
do	do	do	3.90	686
do	do	do	4.90	1,327
do	do	do	4.50	1,226
do	do	do	5.35	2,179
do	do	do	3.00	355
do	do	do	2.70	139
do	do	do	2.80	159
Solomon River	Niles, Kans.	do	5.70	227
do	do	do	5.40	157
do	do	do	5.10	116
do	do	do	5.50	156
do	do	do	6.00	235
do	do	do	4.70	94
do	do	do	4.20	50
do	do	do	4.30	49
Saline River	Salina, Kans.	do	3.30	50
do	do	do	2.80	32
do	do	do	2.70	39
do	do	do	3.20	71
do	do	do	3.50	76
do	do	do	2.70	33
do	do	do	2.20	14
do	do	do	6.80	*a* 355
do	do	do	8.15	*b* 512
do	do	do	10.45	*c* 718
do	do	do	2.60	20
Smoky Hill River	Ellsworth, Kans.	do	1.30	26
do	do	do	1.05	28
do	do	do	1.30	42
do	do	do	1.85	134
do	do	do	4.20	1,083
do	do	do	1.80	142
do	do	do	1.10	29
do	do	do	1.40	39
do	do	do	1.50	75
do	do	do	2.15	206
do	do	do	1.05	16
Blue River	Manhattan, Kans.	O. P. Hood	5.00	1,056
do	do	do	7.00	2,419
do	do	do	13.70	10,780
do	do	do	3.80	423
Kansas River	Lawrence, Kans.	E. C. Murphy	1.08	3,226
do	do	do	1.43	4,529
do	Lecompton, Kans. *d*	do	—.32	954

a 2 p. m.
b 6 p. m.
c 7 a. m.
d Miscellaneous measurements.

Daily gage height, in feet, of Blue River at Manhattan, Kansas, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.50	4.05	4.65	4.20	7.95	8.85	5.00	4.00	3.50	3.90	3.65	4.00
2	4.50	4.00	4.60	4.35	7.10	7.90	4.70	4.00	3.45	3.95	3.80	4.10
3	4.60	4.10	4.60	4.30	6.05	7.45	4.35	4.10	3.40	4.00	3.95	4.20
4	4.60	4.20	4.60	4.40	6.45	7.20	4.15	4.05	3.50	3.90	4.05	4.05
5	4.60	4.30	4.50	4.55	6.80	7.20	4.00	4.00	3.60	3.85	3.95	4.00
6	4.50	4.30	4.45	6.00	7.25	6.75	4.20	4.05	3.55	3.75	4.05	3.90
7	4.50	4.40	4.35	5.80	7.40	9.00	4.40	3.90	3.50	3.70	3.95	3.90
8	4.40	4.25	4.25	5.70	7.30	12.00	4.65	3.95	3.60	3.60	3.80	3.85
9	4.40	4.45	4.20	5.40	7.20	13.70	4.95	4.10	3.60	3.55	3.70	4.15
10	4.25	4.60	4.05	5.15	7.00	13.20	5.25	4.00	3.75	3.50	3.70	4.15
11	4.20	9.60	4.10	4.70	6.70	13.00	5.45	3.95	3.85	3.45	3.75	4.10
12	4.20	10.15	4.35	4.60	6.30	13.35	5.35	3.85	3.95	3.40	3.70	4.10
13	4.30	9.85	4.55	4.90	5.95	12.80	5.10	3.80	4.15	3.45	3.80	4.00
14	4.30	9.25	4.70	5.05	7.95	11.50	4.70	3.90	4.30	3.45	3.90	4.05
15	4.30	8.80	4.75	5.40	7.80	10.75	4.50	3.95	4.25	3.35	3.80	4.15
16	4.45	8.20	4.70	5.45	6.40	10.10	4.40	4.00	4.15	3.40	3.70	4.15
17	4.50	7.55	4.80	5.30	5.85	9.70	4.40	4.00	4.00	3.55	3.75	4.10
18	4.60	7.35	4.90	6.20	5.75	9.40	4.30	4.10	3.85	3.60	3.85	4.05
19	4.60	7.25	4.95	8.15	6.20	9.05	4.25	4.20	3.75	3.75	3.90	4.35
20	4.50	7.15	5.00	7.65	10.30	8.75	4.10	4.10	3.65	3.65	3.80	4.40
21	4.50	7.05	4.75	7.35	12.45	8.40	4.00	4.05	3.60	3.70	3.85	4.45
22	4.60	7.00	4.60	6.40	11.50	8.05	4.00	4.00	3.55	3.75	3.85	4.40
23	4.60	6.70	4.45	5.65	11.65	7.40	4.20	3.95	3.55	3.75	3.85	4.30
24	4.60	6.35	4.30	5.90	10.90	6.90	4.30	3.85	3.75	4.25	3.95	4.45
25	4.50	6.00	4.25	6.75	10.05	6.25	4.20	3.75	3.75	4.15	4.10	4.40
26	4.45	5.70	4.25	6.10	9.70	5.90	4.15	3.65	3.60	3.95	4.00	4.35
27	4.35	5.40	4.15	5.80	9.40	5.55	4.10	3.60	3.55	3.85	4.00	4.45
28	4.25	4.70	4.25	5.60	9.25	5.45	4.00	3.50	3.50	3.70	4.05	4.45
29	4.20	.....	4.30	5.85	9.05	5.20	4.10	3.45	3.65	3.55	4.00	4.50
30	4.15	.....	4.30	6.20	8.55	5.05	4.00	3.40	3.80	3.45	3.95	4.45
31	4.10	.....	4.30	.....	8.10	.....	4.10	3.45	.....	3.45	.....	4.50

Daily gage height, in feet, of Kansas River at Lawrence, Kansas, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	0.10	0.20	0.80	0.60	3.70	3.70	1.50	0.40	−0.40	0.00	0.10	−1.30
2	.20	− .10	.80	.60	4.90	3.60	1.40	.40	− .40	.20	− .05	−1.15
3	.10	− .40	.80	.70	4.00	2.90	1.60	.30	− .40	.00	− .10	+ .10
4	.20	.00	.70	.80	3.10	2.50	1.60	.20	+ .40	− .30	− .05	−2.00
5	.20	.00	.60	1.80	2.50	2.60	1.50	.20	.40	− .80	+ .05	−1.60
6	.20	.40	.60	1.40	2.50	2.10	1.40	.20	.40	−1.10	.15	− .20
7	.20	.60	.60	1.10	2.90	2.00	1.40	.20	.60	−1.20	.10	−1.20
8	.20	.60	.60	1.00	2.60	2.40	1.40	.20	.60	−1.00	.00	− .90
9	.40	.60	.60	1.00	2.10	5.10	1.10	.20	.80	.00	− .15	−2.25
10	.30	.60	.60	1.00	2.00	5.60	1.00	.20	1.00	.00	− .25	−1.45
11	.30	1.00	.60	1.00	1.90	5.20	1.00	.20	1.00	− .80	− .15	− .20
12	.30	1.40	.60	.80	1.70	5.20	.90	.20	1.00	− .90	− .20	− .80
13	.40	1.40	.60	1.00	1.70	4.90	.90	.20	1.00	−1.10	+ .25	−1.60
14	.40	1.40	.60	1.10	3.20	4.70	.90	.20	.90	−1.00	.15	−1.10
15	.40	2.00	.80	1.10	5.25	4.20	.90	.20	.70	−1.00	− .40	−1.10
16	.40	1.80	.70	1.00	5.10	4.40	.80	.20	.20	+ .30	− .25	−1.90
17	.40	1.70	.70	1.10	4.60	3.90	.80	.20	.10	.35	− .10	− .40
18	.40	1.40	.80	1.10	3.90	3.20	.80	.80	.20	.20	− .10	− .50
19	.40	1.40	1.00	1.00	3.40	3.70	.80	.90	.40	.15	.00	− .60
20	.40	1.40	1.20	.90	3.20	3.60	.80	.80	.40	.30	.15	− .60
21	.30	1.20	1.20	1.70	3.35	3.20	.70	.60	.25	.30	− .10	+ .90
22	.30	1.00	1.20	1.90	4.20	2.80	.60	.50	.20	.20	−2.15	1.00
23	.40	1.00	1.20	2.00	4.10	2.50	.60	.30	.05	.35	−1.00	1.00
24	.40	.90	1.10	1.80	4.00	2.30	.60	.20	.00	.25	− .90	1.30
25	.40	.80	.90	1.70	3.70	2.40	.60	.20	.20	− .30	−1.00	1.40
26	.20	.80	.80	1.50	2.90	2.30	.50	.00	.30	−1.40	−1.70	1.20
27	.20	.80	1.60	1.40	3.90	2.20	.40	.00	.35	− .30	+ .10	1.20
28	.40	.80	2.00	1.30	5.10	1.90	.40	.00	.50	− .15	− .90	1.00
29	.40	.....	1.40	1.20	4.70	1.70	.40	− .20	.35	− .10	−1.00	1.05
30	.40	.....	.90	1.80	3.80	1.60	.40	− .40	.10	+ .20	−1.10	1.00
31	.30	.....	.60	.....	3.20	.....	.60	− .40	.....	.30	.....	.70

Gallons into cubic feet.

1 United States liquid gallon = 231 cubic inches = $\frac{231}{1,728}$ cubic foot = 0.13368055 cubic feet.

[In cubic feet.]

gallon	0.13368055	6 gallons	0.80208330
gallons	.26736110	7 gallons	.93576385
gallons	.40104165	8 gallons	1.06944440
gallons	.53472220	9 gallons	1.20312495
gallons	.66840275		

	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
0	.....	0.1337	0.2674	0.4010	0.5347	0.6684	0.8021	0.9358	1.0694	1.2031
10	1.3368	1.4705	1.6042	1.7378	1.8715	2.0052	2.1389	2.2726	2.4062	2.5399
20	2.6736	2.8073	2.9410	3.0746	3.2083	3.3420	3.4757	3.6094	3.7430	3.8767
30	4.0104	4.1441	4.2778	4.4114	4.5451	4.6788	4.8125	4.9462	5.0798	5.2135
40	5.3472	5.4809	5.6146	5.7482	5.8819	6.0156	6.1493	6.2830	6.4166	6.5503
50	6.6840	6.8177	6.9514	7.0850	7.2187	7.3524	7.4861	7.6198	7.7534	7.8871
60	8.0208	8.1545	8.2882	8.4218	8.5555	8.6892	8.8229	8.9566	9.0902	9.2239
70	9.3576	9.4913	9.6250	9.7586	9.8923	10.0260	10.1597	10.2934	10.4270	10.5607
80	10.6944	10.8281	10.9618	11.0954	11.2291	11.3628	11.4965	11.6302	11.7638	11.8975
90	12.0312	12.1649	12.2986	12.4322	12.5659	12.6996	12.8333	12.9670	13.1006	13.2343

Feet per second into miles per hour.

1 foot per second = 3,600 feet per hour = $\frac{3,600}{5,280}$ or $\frac{15}{22}$ miles per hour.

[In miles per hour.]

›ot per second	0.68182	6 feet per second	4.09091
›et per second	1.36364	7 feet per second	4.77273
›et per second	2.04545	8 feet per second	5.45455
›et per second	2.72727	9 feet per second	6.13636
›et per second	3.40909		

See Smithsonian Meteorological Tables, No. 52.)

	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
0	.....	0.6818	1.3636	2.0455	2.7273	3.4091	4.0909	4.7727	5.4546	6.1364
10	6.8182	7.5000	8.1818	8.8637	9.5455	10.2273	10.9091	11.5909	12.2728	12.9546
20	13.6336	14.3182	15.0000	15.6819	16.3637	17.0455	17.7273	18.4091	19.0910	19.7728
30	20.4546	21.1364	21.8182	22.5001	23.1819	23.8637	24.5455	25.2273	25.9092	26.5910
40	27.2728	27.9546	28.6364	29.3183	30.0001	30.6819	31.3637	32.0455	32.7274	33.4092
50	34.0910	34.7728	35.4546	36.1365	36.8183	37.5001	38.1819	38.8637	39.5456	40.2274
60	40.9092	41.5910	42.2728	42.9547	43.6365	44.3183	45.0001	45.6819	46.3638	47.0456
70	47.7274	48.4092	49.0910	49.7729	50.4547	51.1365	51.8183	52.5001	53.1820	53.8638
80	54.5456	55.2274	55.9092	56.5911	57.2729	57.9547	53.6365	59.3183	60.0002	60.6820
90	61.3638	62.0456	62.7274	63.4093	64.0911	64.7729	65.4547	66.1365	66.8184	67.5002

Miles per hour into feet per second.

1 mile per hour = 5,280 feet per hour = $\frac{5,280}{3,600}$ or $\frac{22}{15}$ feet per second.

[In feet per second.]

ile per hour	1.46667	6 miles per hour	8.80000
iles per hour	2.93333	7 miles per hour	10.26667
iles per hour	4.40000	8 miles per hour	11.73333
iles per hour	5.86667	9 miles per hour	13.20000
iles per hour	7.33333		

See Smithsonian Meteorological Tables, No. 51.)

	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
0	.....	1.4667	2.9333	4.4000	5.8667	7.3333	8.8000	10.2667	11.7333	13.2000
10	14.6667	16.1333	17.6000	19.0667	20.5333	22.0000	23.4667	24.9333	26.4000	27.8667
20	29.3333	30.8000	32.2667	33.7333	35.2000	36.6667	38.1333	39.6000	41.0667	42.5333
30	44.0000	45.4667	46.9333	48.4000	49.8667	51.3333	52.8000	54.2667	55.7333	57.2000
40	58.6667	60.1333	61.6000	63.0667	64.5333	66.0000	67.4667	68.9333	70.4000	71.8667
50	73.3333	74.8000	76.2667	77.7333	79.2000	80.6667	82.1333	83.6000	85.0667	86.5333
60	88.0000	89.4667	90.9333	92.4000	93.8667	95.3333	96.8000	98.2667	99.7333	101.2000
70	102.6667	104.1333	105.6000	107.0667	108.5333	110.0000	111.4667	112.9333	114.4000	115.8667
80	117.3333	118.8000	120.2667	121.7333	123.2000	124.6667	126.1333	127.6000	129.0667	130.5333
90	132.0000	133.4667	134.9333	136.4000	137.8667	139.3333	140.8000	142.2667	143.7333	145.2000

Rating tables.

Junction City.		Niles.		Salina.		Ellsworth.		Manhattan.		Lawrence.	
Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
2.0	28	4.0	40	2.0	6	0.8	14	3.0	50	—1.9	542
2.2	44	4.2	50	2.2	10	.9	16	3.2	140	—1.8	552
2.4	69	4.4	62	2.4	15	1.0	18	3.4	230	—1.6	572
2.6	110	4.6	75	2.6	22	1.1	24	3.6	320	—1.4	592
2.8	175	4.8	92	2.8	32	1.2	32	3.8	410	—1.2	612
3.0	252	5.0	115	3.0	40	1.3	42	4.0	500	—1.0	632
3.2	325	5.2	137	3.2	52	1.4	55	4.5	775	—.8	652
3.4	425	5.4	160	3.4	63	1.5	70	5.0	1,050	—.6	672
3.6	530	5.6	184	3.6	79	1.6	86	5.5	1,365	—.4	692
3.8	645	5.8	209	3.8	94	1.7	105	6.0	1,680	—.2	712
4.0	760	6.0	238	4.0	109	1.8	126	6.5	2,050	.0	787
4.2	900	6.2	268	4.2	125	1.9	147	7.0	2,420	.2	967
4.4	1,055	6.4	299	4.4	139	2.0	170	7.5	2,810	.4	1,255
4.6	1,220	6.6	335	4.6	157	2.1	196	8.0	3,200	.6	1,643
4.8	1,420	6.8	371	4.8	175	2.2	225	8.5	3,650	.8	2,123
5.0	1,675	7.0	406	5.0	193	2.3	253	9.0	4,100	1.0	2,687
5.2	1,970	7.2	441	5.2	209	2.4	283	9.5	4,615	1.5	4,412
5.4	2,250	7.4	480	5.4	225	2.5	312	10.0	5,130	2.0	6,490
5.6	2,560	7.6	522	5.6	243	2.6	343	10.5	5,760	2.5	8,840
5.8	2,900	7.8	570	5.8	261	2.7	376	11.0	6,390	3.0	11,440
6.0	3,245	8.0	619	6.0	279	2.8	410	11.5	7,080	3.5	14,290
6.2	3,610	8.2	664	6.5	324	2.9	450	12.0	7,770	4.0	17,390
6.4	3,975	8.4	718	7.0	373	3.0	490	12.5	8,635	4.5	20,740
6.6	4,350	8.6	760	7.5	421	3.2	573	13.0	9,500	5.0	24,340
6.8	4,780	8.8	808	8.0	470	3.4	670	13.5	10,410	5.5	28,190
7.0	5,200	9.0	854	8.5	519	3.6	763	14.0	11,320	6.0	32,290
7.2	5,610	9.5	973	9.0	569	3.8	867	14.5	12,215	6.5	36,640
7.4	6,050	10.0	1,100	9.5	620	4.0	975	15.0	13,110	7.0	41,290
.....	.....	.....	.....	10.0	673	.....	.....	15.5	14,005	.....	.....
.....	.....	.....	.....	10.5	732	.....	.....	16.0	14,900	.....	.....

CONVERSION TABLES.

The following tables for converting common units employed in water measurement have been inserted for the purpose of facilitating computations. At the head of each table is placed the factor used, this in the case of decimals being carried out usually to seven places.

Cubic feet into gallons.

$$1 \text{ cubic foot} = 1{,}728 \text{ cubic inches} = \frac{1{,}728}{231} \text{ gallons} = 7.4805194 \text{ gallons.}$$

[In gallons.]

1 cubic foot	7.4805194	6 cubic feet	44.88311
2 cubic feet	14.9610388	7 cubic feet	52.36363
3 cubic feet	22.4415582	8 cubic feet	59.84415
4 cubic feet	29.9220776	9 cubic feet	67.32467
5 cubic feet	37.4025970		

	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
0	.....	7.48	14.96	22.44	29.92	37.40	44.88	52.36	59.84	67.32
10	74.81	82.26	89.77	97.25	104.73	112.21	119.69	127.17	134.65	142.13
20	149.61	157.09	164.57	172.05	179.53	187.01	194.49	201.97	209.45	216.94
30	224.42	231.90	239.38	246.86	254.34	261.82	269.30	276.78	284.26	291.74
40	299.22	306.70	314.18	321.66	329.14	336.62	344.10	351.58	359.06	366.55
50	374.03	381.51	388.99	396.47	403.95	411.43	418.91	426.39	433.87	441.35
60	448.83	456.31	463.79	471.27	478.75	486.23	493.71	501.19	508.68	516.16
70	523.64	531.12	538.60	546.08	553.56	561.04	568.52	576.00	583.48	590.96
80	598.44	605.92	613.40	620.88	628.36	635.84	643.32	650.81	658.29	665.77
90	673.25	680.73	688.21	695.69	703.17	710.65	718.13	725.61	733.09	740.57

Acre-feet into second-feet flow for 24 hours.

cot each 24 hours = 43,560 cubic feet each 86,400 seconds = $\frac{43,560}{86,400}$, or $\frac{121}{240}$ second-foot flow for 24 hours.

[In second-feet for 24 hours.]

.....	.50417	6 acre-feet.....	3.02500
.....	1.00833	7 acre-feet.....	3.52917
.....	1.51250	8 acre-feet.....	4.03334
.....	2.01667	9 acre-feet.....	4.53750
.....	2.52084		

	1.	2.	3.	4.	5.	6.	7.	8.	9.
...	.504	1.008	1.513	2.017	2.521	3.025	3.529	4.033	4.538
42	5.546	6.050	6.554	7.058	7.563	8.067	8.571	9.075	9.579
83	10.588	11.092	11.596	12.100	12.604	13.108	13.613	14.117	14.621
25	15.629	16.133	16.638	17.142	17.646	18.150	18.654	19.158	19.663
67	20.671	21.175	21.679	22.183	22.688	23.192	23.696	24.200	24.704
09	25.713	26.217	26.721	27.225	27.729	28.234	28.738	29.242	29.746
50	30.754	31.259	31.763	32.267	32.771	33.275	33.779	34.284	34.788
92	35.796	36.300	36.804	37.309	37.813	38.317	38.821	39.325	39.829
34	40.838	41.342	41.846	42.350	42.854	43.359	43.863	44.367	44.871
75	45.880	46.384	46.888	47.392	47.896	48.400	48.905	49.409	49.913

Acre-feet into millions of gallons.

cre-foot = 43,560 cubic feet = $\frac{43,560 \times 1,728}{231}$ or $\frac{75,271,680}{231}$, or 325,851.428 gallons.

[In gallons.]

	Millions.	Thousands.		Millions.	Thousands.
.....	0.325851428	325.9	6 acre-feet	1.95510858	1,955.1
.....	.65170286	651.7	7 acre-feet	2.28096001	2,281.0
.....	.97755429	977.6	8 acre-feet	2.60681144	2,606.8
.....	1.30340572	1,303.4	9 acre-feet	2.93266287	2,932.7
.....	1.62925715	1,629.3			

	1.	2.	3.	4.	5.	6.	7.	8.	9.
...	0.3259	0.6517	0.9776	1.3034	1.6293	1.9551	2.2810	2.6068	2.9327
85	3.5844	3.9102	4.2361	4.5619	4.8878	5.2136	5.5395	5.8653	6.1912
70	5.8429	7.1687	7.4946	7.8204	8.1463	8.4721	8.7980	9.1238	9.4497
55	10.1014	10.4272	10.7531	11.0789	11.4048	11.7306	12.0565	12.3823	12.7082
41	13.3599	13.6857	14.0116	14.3374	14.6633	14.9891	15.3150	15.6408	15.9667
26	16.6184	16.9443	17.2701	17.5960	17.9218	18.2477	18.5735	18.8994	19.2252
11	19.8769	20.2028	20.5286	20.8545	21.1803	21.5062	21.8320	22.1579	22.4837
96	23.1354	23.4613	23.7871	24.1130	24.4388	24.7647	25.0905	25.4164	25.7422
81	26.3939	26.7198	27.0456	27.3715	27.6973	28.0232	28.3490	28.6749	29.0007
66	29.6524	29.9783	30.3041	30.6300	30.9558	31.2817	32.6075	31.9334	32.2592

Millions of gallons into acre-feet.

United States liquid gallons or 231 million cubic inches = 133,680.555 cubic feet, or

$$\frac{133,680}{43,560} = 3.0688832 \text{ acre-feet.}$$

[In acre-feet.]

llons.....	3.0688832	6 million gallons.....	18.4132993
llons.....	6.1377664	7 million gallons.....	21.4821826
llons.....	9.2066496	8 million gallons.....	24.5510659
llons.....	12.2755328	9 million gallons.....	27.6199492
llons.....	15.3444160		

	1.	2.	3.	4.	5.	6.	7.	8.	9.
...	3.069	6.138	9.207	12.276	15.344	18.413	21.482	24.551	27.620
89	33.758	36.827	39.895	42.964	46.033	49.102	52.171	55.240	58.309
78	64.446	67.515	70.584	73.653	76.722	79.791	82.860	85.929	88.998
66	95.135	98.204	101.273	104.342	107.411	110.480	113.549	116.618	119.686
55	125.824	128.893	131.962	135.031	138.100	141.169	144.238	147.306	150.375
44	156.513	159.582	162.651	165.720	168.789	171.857	174.926	177.995	181.064
33	187.202	190.271	193.340	196.409	199.477	202.546	205.615	208.684	211.753
22	217.891	220.960	224.028	227.097	230.166	233.235	236.304	239.373	242.442
11	248.580	251.648	254.717	257.786	260.855	263.924	266.993	270.062	273.131
99	279.268	282.337	285.406	288.475	291.544	294.613	297.682	300.751	303.819

Second-feet into minute-gallons.

Factors: 1 cubic foot contains 1,728 cubic inches; 1 gallon has a capacity of 231 cubic second-foot equals [(1,728 ÷ 231) × 60] gallons per minute, or 448.831164 minute-gal

[In gallons per minute.]

1 second-foot	448.831164	6 second-feet	2,
2 second-feet	897.662328	7 second-feet	3,
3 second-feet	1,346.493492	8 second-feet	3,
4 second-feet	1,795.324656	9 second-feet	4,
5 second-feet	2,244.155820		

	0.	1.	2.	3.	4.	5.	6.	7.	8.
0	.....	449	898	1,346	1,795	2,244	2,693	3,142	3,591
10	4,488	4,937	5,386	5,835	6,284	6,732	7,181	7,630	8,079
20	8,977	9,425	9,874	10,323	10,772	11,221	11,670	12,118	12,567
30	13,465	13,914	14,363	14,811	15,260	15,709	16,158	16,607	17,056
40	17,953	18,402	18,851	19,300	19,749	20,197	20,646	21,095	21,544
50	22,442	22,890	23,339	23,788	24,237	24,686	25,135	25,583	26,032
60	26,930	27,379	27,828	28,276	28,725	29,174	29,623	30,072	30,521
70	31,418	31,867	32,316	32,765	33,214	33,662	34,111	34,560	35,009
80	35,906	36,355	36,804	37,253	37,702	38,151	38,599	39,048	39,497
90	40,395	40,844	41,292	41,741	42,190	42,639	43,088	43,537	43,985

Minute-gallons into second-feet.

Factors: 1 gallon contains 231 cubic inches; 1 cubic foot contains 1,728 cubic inches; 1 minute equals [(231÷1,728)÷60] second-feet, or .002,228,009, 2 second-feet.

[In second-feet.]

1 minute-gallon	0.002,228,009	6 minute-gallons	0.(
2 minute-gallons	.004,456,018	7 minute-gallons	.(
3 minute-gallons	.006,684,028	8 minute-gallons	.(
4 minute-gallons	.008,912,037	9 minute-gallons	.(
5 minute-gallons	.011,140,046		

	0.	1.	2.	3.	4.	5.	6.	7.	8.
0	.....	0.0022	0.0045	0.0067	0.0089	0.0111	0.0134	0.0156	0.0178
10	0.0223	.0245	.0267	.0290	.0312	.0334	.0356	.0379	.0401
20	.0446	.0468	.0490	.0512	.0535	.0557	.0579	.0602	.0624
30	.0668	.0691	.0713	.0735	.0758	.0780	.0802	.0824	.0847
40	.0891	.0913	.0936	.0958	.0980	1.0026	1.0249	1.0472	1.0694
50	1.1140	1.1363	1.1586	1.1808	1.2031	1.2254	1.2477	1.2700	1.2922
60	1.3368	1.3591	1.3814	1.4036	1.4259	1.4482	1.4705	1.4928	1.5150
70	1.5596	1.5819	1.6042	1.6264	1.6487	1.6710	1.6933	1.7156	1.7378
80	1.7824	1.8047	1.8270	1.8492	1.8715	1.8938	1.9161	1.9384	1.9606
90	2.0052	2.0275	2.0498	2.0720	2.0943	2.1166	2.1389	2.1612	2.1834

[For index, see Part II of this report—Water-Supply Paper No. 28

DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 28

WASHINGTON
GOVERNMENT PRINTING OFFICE
1899

Second-feet into minute-gallons.

Factors: 1 cubic foot contains 1,728 cubic inches; 1 gallon has a capacity of 231 cubic second-foot equals [(1,728 ÷ 231) × 60] gallons per minute, or 448.831164 minute-gal

[In gallons per minute.]

1 second-foot	448.831164	6 second-feet	2,
2 second-feet	897.662328	7 second-feet	3,
3 second-feet	1,346.493492	8 second-feet	3,
4 second-feet	1,795.324656	9 second-feet	4,
5 second-feet	2,244.155820		

	0.	1.	2.	3.	4.	5.	6.	7.	8.
0	.....	449	898	1,346	1,795	2,244	2,693	3,142	3,591
10	4,488	4,937	5,386	5,835	6,284	6,732	7,181	7,630	8,079
20	8,977	9,425	9,874	10,323	10,772	11,221	11,670	12,118	12,567
30	13,465	13,914	14,363	14,811	15,260	15,709	16,158	16,607	17,056
40	17,953	18,402	18,851	19,300	19,749	20,197	20,646	21,095	21,544
50	22,442	22,890	23,339	23,788	24,237	24,686	25,135	25,583	26,032
60	26,930	27,379	27,828	28,276	28,725	29,174	29,623	30,072	30,521
70	31,418	31,867	32,316	32,765	33,214	33,662	34,111	34,560	35,009
80	35,906	36,355	36,804	37,253	37,702	38,151	38,599	39,048	39,497
90	40,395	40,844	41,292	41,741	42,190	42,639	43,088	43,537	43,985

Minute-gallons into second-feet.

Factors: 1 gallon contains 231 cubic inches; 1 cubic foot contains 1,728 cubic inches; 1 g minute equals [(231÷1,728)÷60] second-feet, or .002,228,009, 2 second-feet.

[In second-feet.]

1 minute-gallon	0.002,228,009	6 minute-gallons	0.0
2 minute-gallons	.004,456,018	7 minute-gallons	.0
3 minute-gallons	.006,684,028	8 minute-gallons	.0
4 minute-gallons	.008,912,037	9 minute-gallons	.0
5 minute-gallons	.011,140,046		

	0.	1.	2.	3.	4.	5.	6.	7.	8.
0	.....	0.0022	0.0045	0.0067	0.0089	0.0111	0.0134	0.0156	0.0178
10	0.0223	.0245	.0267	.0290	.0312	.0334	.0356	.0379	.0401
20	.0446	.0468	.0490	.0512	.0535	.0557	.0579	.0602	.0624
30	.0668	.0691	.0713	.0735	.0758	.0780	.0802	.0824	.0847
40	.0891	.0913	.0936	.0958	.0980	1.0026	1.0249	1.0472	1.0694
50	1.1140	1.1363	1.1586	1.1808	1.2031	1.2254	1.2477	1.2700	1.2922
60	1.3368	1.3591	1.3814	1.4036	1.4259	1.4482	1.4705	1.4928	1.5150
70	1.5596	1.5819	1.6042	1.6264	1.6487	1.6710	1.6933	1.7156	1.7378
80	1.7824	1.8047	1.8270	1.8492	1.8715	1.8938	1.9161	1.9384	1.9606
90	2.0052	2.0275	2.0498	2.0720	2.0943	2.1166	2.1389	2.1612	2.1834

[For index, see Part II of this report—Water-Supply Paper No. 28

DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

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UNITED STATES GEOLOGICAL SURVEY

No. 28

WASHINGTON
GOVERNMENT PRINTING OFFICE
1899

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

OPERATIONS AT RIVER STATIONS, 1898

A REPORT OF THE

DIVISION OF HYDROGRAPHY

OF THE

UNITED STATES GEOLOGICAL SURVEY

PART II

WASHINGTON
GOVERNMENT PRINTING OFFICE
1899

CONTENTS.

	Page.
Letter of transmittal	106
Arkansas River drainage	107
Western Gulf drainage	118
Colorado River drainage	131
Interior basin drainage	145
Columbia River drainage	155
Northern Pacific coast drainage	171
San Francisco Bay drainage	177
Southern California drainage	186
Index	197

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, March 2, 1899.

SIR: I have the honor to transmit herewith brief descriptions of the river stations in the western portion of the country at which work was carried on by the Division of Hydrography of this Survey during 1898, together with tables of daily height and related data, for publication in the series of Water-Supply and Irrigation Papers. The data for the eastern and central portions of the country (Part I) have been transmitted as the preceding number of the series.

In this paper (pp. 193–196) is given a list of low-water measurements made in California during 1898. This work was carried on by Mr. J. B. Lippincott, who states that the season of 1897–98 was one of unusual drought throughout the State. The average rainfall for the city of Los Angeles between the years 1871 and 1898 was 16.59 inches, but for 1897–98 it was only 7.10 inches and for 1898–99 to May 1 it was 4.91 inches, resulting in extraordinarily low stream flow. During the nine years ending in 1898 the precipitation for only one season has substantially exceeded the average of 16.59 inches. During another year it has been slightly in excess, but during the remaining seven years the precipitation has been below this average, and during four of these seven years the deficiency has been very marked. Objection has been made to the publication of these measurements of low-water flow as prejudicial to private interests, but it is believed to be highly important to give the facts as obtained. At the same time it should be clearly stated that absolute correctness is not claimed for measurements of this character, but that the results are accurate within ordinary or practical requirements, being as complete as is possible with the available funds. The results furnish a fair general indication of the flow of the streams. The measurements made with current meters are known to be reliable, and the volumes determined from the intermediate rod readings are approximately correct within the limit assignable to ordinary engineering estimates.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

OPERATIONS AT RIVER STATIONS, 1898.

PART II.

ARKANSAS RIVER DRAINAGE.

DESCRIPTION OF RIVER STATIONS.

Granite station on Arkansas River.—Described on page 117 of Paper No. 16; results for 1897 given on page 353 of the Nineteenth Annual Report, Part IV. The observer is W. R. Reed. The record has been kept only for August and September, 1898.

Salida station on Arkansas River.—Described on page 118 of Paper No. 16; results for 1897 given on pages 354–355 of the Nineteenth Annual Report, Part IV. The observer is William Furniss.

Canyon station on Arkansas River.—Described on page 119 of Paper No. 16; results for 1897 given on pages 355–356 of the Nineteenth Annual Report, Part IV.

Pueblo station on Arkansas River.—Described on page 120 of Paper No. 16; results for 1897 given on page 356 of the Nineteenth Annual Report, Part IV. Neither of the rods described in Paper No. 16 are now being used, being replaced by one at Main Street Bridge, described below, where measurements for all three rods have been made. The river is confined by city levees, and the bed is sandy and constantly changing. The observer was R. L. Holden up to August 31, at which time observations were abandoned at the Santa Fe Avenue Bridge, being replaced by those taken at Main Street Bridge. The list of discharge measurements for this station will be found under the heading of Main street station, they being applicable to both points, and all having been taken at the Main Street Bridge, which is located between Santa Fe Avenue and Victoria Avenue bridges.

This station, as above stated, is intended to take the place of the Santa Fe Avenue Bridge at Pueblo, from which reports were received up to September 1, but which was abandoned because of the cutting down of the bed of the river and the unreliability of the reports. The new station on the east side of Main Street Bridge was established July 10, 1898, by A. L. Fellows. The gage rod consists of an inclined 2 by 6 inch by 15-foot plank, with a slope from the vertical of 4.6 feet in 15 feet. The space between the marks on the rod is 0.104; the gage rod is well painted and is fastened by iron bolts in the masonry wall. The initial point for sounding is the north end of the bridge on the east side. The channel is straight above and below for about 1,000 feet, and is of gravel and sand. The banks are high city embankments of slag and masonry and are not liable to over-

flow. The cross section of the channel is good, but fills up somewhat in low water and scours in high water. The observer is Mr. C. W. Reece, water commissioner of district No. 14. Readings are also taken at this point by the Pueblo city engineer.

Nepesta station on Arkansas River.—Described on page 121 of Paper No. 16; results for 1897 given on page 358 of the Nineteenth Annual Report, Part IV. S. M. Butts was observer until July 2, and J. P. Haines for balance of the year.

Rocky Ford station on Arkansas River.—Described on page 122 of Paper No. 16.

Manzanola station on Arkansas River.—This station is located about one-half of a mile north of Manzanola, Colorado, at a wagon bridge, and was first established September 29, 1897, by Porter J. Preston, when a measurement was made, showing a discharge of 208 second-feet. The rod was changed in May, 1898, however, and is now nailed to a 2 by 4 inch timber, which is securely fastened to an iron pier in the center of the stream. The rod consists of a 2 by 6 inch by 12-foot timber, marked in tenths by means of a 1 by 6 inch scale. The initial point for soundings is on the right bank, which is high, while the left is low and liable to overflow. The river bends at this point and is not straight for any considerable distance above or below, but the channel, which is in sand and gravel, is not liable to much change. The observer was M. D. Lyle, a ditch rider on the Catlin Canal. No sufficient number of discharge measurements were made upon which to base a rating table.

Trinidad station on Purgatory River.—Described on page 123 of Paper No. 16; results for 1897 given on pages 358–360 of the Nineteenth Annual Report, Part IV.

J. J. Ranch station on Purgatory River.—This station is located 22 miles south of Lajunta, Colorado, and is approximately 27 miles above the mouth of the Purgatory River. The gage rod is placed one-half mile below the mouth of Smith Canyon, a large tributary of the Purgatory. It is nailed to a pole, which is securely fastened by means of stakes driven into the bank. The rod was originally graduated for a vertical position, but was afterwards placed in a sloping position. The elevations of the several footmarks were taken with a wye level, and a correction table was made, giving the corresponding vertical values for the inclined rod. The elevation of the gage rod was established in reference to a bench mark placed on the foot of a large cottonwood tree. The river channel is straight for a distance of 400 feet above and 250 feet below the gage rod. The bottom is of gravel, and there is considerable fall both above and below the rod. The discharge measurements were taken in 1898 by C. W. Beach, but owing to the fact that the two gagings were made at times when the gage rod was in different positions, there is no known relationship between them, and no rating table was constructed. The observer is Edward Sanborn, a ranch laborer.

Las Animas station on Arkansas River.—This station is located about one-half of a mile north of Las Animas, Colorado, at a wagon bridge, having been established May 13, 1898. The gage consists of a 1 by 5 inch board marked in tenths and wired securely to an iron bridge pier on south side of river and upstream side of bridge. The river is straight for 200 feet above and 300 feet below; the bed is sandy and shifting. The banks are not liable to overflow excepting at very high water. The observer was C. W. Beach in May and C. L. Morris after July 19. No gagings were made in 1898.

Amity Canal headgates on the Arkansas River.—This station is located at the head of the Amity Canal, 7 miles west of Lamar, Colorado. The canal is taken out on the north side of the river at a point where there is a wooden dam extending across the stream. The dam is 365 feet long; the crest of the last 81 feet on the south side is 15 inches higher than the crest of the remaining 284 feet, which latter is 4 feet and 4 inches above the floor of the head gates. The river at this point washes against a sandstone bluff. The dam makes the river channel unchangeable, and, taken in connection with the canal, it furnishes an excellent place for obtaining the total discharge of the Arkansas River at this point. During the past year the gagings of the canal have been taken in its rating flume; this necessitates a separate gage for crest of dam. It is expected, however, that on January 1, 1899, one gage rod will be so placed as to serve both for the dam and the canal. The observer is Mr. E. R. Bannister, headgate keeper of the Amity Canal.

Granada station on Arkansas River.—This station was located at the head gate of the Buffalo Creek Canal, 2 miles northeast of Granada. The equipment consists of a bridge upon the head gate of the canal, there being an earth dam across the Arkansas at this point, which sometimes breaks during high water and has to be repaired, thus making the results of the gage readings of not great value, excepting as showing the rise and fall of the water. The gage rod is vertical and well painted, nailed to the head gate. The channel is straight for about 2,600 feet above and about 800 feet below, and the water runs swiftly both above and below. The banks are high on each side and the bed of the stream is of gravel and more or less changeable. The observer is Ben Riley, a ditch rider of the Buffalo Creek ditch, who takes the observations once each day at 7 a. m. No gagings have been made at this point, as the bed of the stream is so changeable that gagings would be of but little value. It is expected that different arrangements, giving more valuable results, can be made during 1899.

Hutchinson station on Arkansas River.—Described on page 124 of Paper No. 16; results for 1897 given on pages 360–361 of the Nineteenth Annual Report, Part IV.

Liberty station on Verdigris River.—Described on page 125 of Paper No. 16; results for 1897 given on pages 369–372 of the Nineteenth Annual Report, Part IV.

Iola station on Neosho River.—Described on page 126 of Paper No. 16; results for 1897 given on pages 361–363 of the Nineteenth Annual Report, Part IV.

TABLES OF DAILY GAGE HEIGHT.

Daily gage height, in feet, of Arkansas River at Granite, Colorado, for 1898.

Day.	Aug.	Sept.	Day.	Aug.	Sept.	Day.	Aug.	Sept.	Day.	Aug.	Sept.
1	3.50	3.35	9	3.50	3.20	17	3.30	3.10	25	3.45	2.90
2	3.50	3.35	10	3.50	3.20	18	3.30	3.10	26	3.40	2.80
3	3.50	3.35	11	3.50	3.30	19	3.30	3.10	27	3.30	2.80
4	3.50	3.35	12	3.50	3.30	20	3.30	3.10	28	3.30	2.80
5	3.50	3.35	13	3.40	3.30	21	3.30	3.00	29	3.35	2.80
6	3.50	3.35	14	3.30	3.20	22	3.30	3.00	30	3.40	2.80
7	3.50	3.30	15	3.30	3.20	23	3.30	3.00	31	3.35	.....
8	3.50	3.20	16	3.40	3.15	24	3.40	2.90			

Daily gage height, in feet, of Arkansas River at Salida, Colorado, for 1898.

Day.	Aug.	Sept.	Oct.	Nov.	Day.	Aug.	Sept.	Oct.	Nov.	Day.	Aug.	Sept.	Oct.	Nov.
1	1.05	0.90	0.70	0.90	12	0.80	0.80	0.80	0.80	23	0.75	0.70	0.90	0.75
2	1.05	.85	.70	.90	13	.80	.80	.70	.80	24	.85	.70	.90	.80
3	.90	.80	.65	.90	14	.80	.80	.70	.80	25	.90	.70	.90	.85
4	.90	.80	.60	.90	15	.80	.80	.70	.80	26	.85	.70	.90	.80
5	.90	.75	.70	.90	16	.80	.75	.70	.80	27	.80	.70	.90	.80
6	.90	.70	.60	.90	17	.80	.70	.70	.80	28	.80	.70	.90	.80
7	.90	.70	.60	.90	18	.90	.70	.80	.80	29	.80	.70	.90	.80
8	1.00	.70	.70	.80	19	.80	.70	.80	.90	30	.75	.70	.90	.90
9	.90	.70	.75	.80	20	.80	.70	.80	.90	31	.70	.....	.90	.....
10	1.00	.70	.80	.80	21	.80	.70	.80	.90					
11	.90	.90	.80	.80	22	.75	.70	.90	.75					

Daily gage height, in feet, of Arkansas River at Canyon, Colorado, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.50	.....	.....	.....	2.80	3.85	4.00	2.80	2.30	2.10	2.60	.....
2	.....	.....	.....	2.50	2.90	4.10	3.90	2.80	2.20	2.10	2.50	.....
3	.....	.....	.....	.....	3.05	4.20	3.80	2.70	2.20	2.10	2.50	2.70
4	.....	.....	.....	.....	3.20	4.50	3.70	2.60	2.20	2.10	2.50	.....
5	.....	2.60	2.70	.....	3.30	4.50	3.75	2.60	2.20	2.10	2.50	.....
6	.....	.....	.....	.....	3.40	4.15	3.85	2.50	2.20	2.10	2.50	.....
7	.....	.....	.....	.....	3.50	4.10	4.00	2.40	2.20	2.10	2.50	.....
8	2.50	.....	.....	.....	3.40	4.25	4.20	2.65	2.20	2.10	2.45	.....
9	.....	.....	.....	2.70	3.40	4.35	4.15	2.85	2.20	2.10	2.40	.....
10	.....	.....	.....	.....	3.40	4.25	4.00	2.85	2.30	2.10	2.40	2.70
11	.....	.....	.....	.....	3.30	4.30	4.05	2.80	2.30	2.20	2.40	.....
12	.....	2.60	2.60	.....	3.30	4.35	4.35	2.70	2.30	2.25	2.50	.....
13	.....	.....	.....	.....	3.25	4.40	4.50	2.60	2.30	2.30	2.50	.....
14	.....	.....	.....	.....	3.35	4.35	4.75	2.50	2.30	2.30	2.50	.....
15	2.40	.....	.....	.....	3.40	4.45	4.50	2.50	2.30	2.40	2.50	.....
16	.....	.....	.....	3.00	3.30	4.65	4.75	3.25	2.30	2.40	2.60	.....
17	.....	.....	.....	.....	3.30	4.85	4.50	2.65	2.20	2.40	2.60	a 2.60
18	.....	.....	.....	.....	3.20	5.05	4.30	2.55	2.20	2.40	2.60	.....
19	.....	2.70	2.70	.....	3.15	5.15	3.85	2.50	2.20	2.40	2.60	.....
20	.....	.....	.....	.....	3.10	5.15	3.70	2.50	2.20	2.50	2.60	.....
21	.....	.....	.....	.....	3.05	5.00	3.70	2.50	2.20	2.50	2.60	.....
22	2.40	.....	.....	.....	3.05	5.00	3.60	2.50	2.20	2.50	2.60	.....
23	.....	.....	.....	2.70	3.10	4.90	3.50	2.55	2.20	2.50	2.70	.....
24	.....	.....	.....	.....	3.10	4.80	3.50	2.50	2.20	2.50	2.70	a 2.60
25	.....	.....	.....	.....	3.00	4.75	3.50	2.50	2.20	2.50	2.70	.....
26	.....	2.80	2.60	.....	3.05	4.60	3.40	2.45	2.10	2.50	2.70	.....
27	.....	.....	.....	.....	3.25	4.45	3.30	2.40	2.10	2.50	2.70	.....
28	.....	.....	.....	.....	3.50	4.25	3.15	2.40	2.10	2.50	2.70	.....
29	2.60	.....	.....	.....	3.70	4.15	3.00	2.40	2.10	2.60	2.60	.....
30	.....	.....	.....	2.80	3.90	4.05	3.00	2.40	2.10	2.60	2.60	.....
31	.....	.....	.....	.....	3.90	.....	2.90	2.40	.....	2.60	.....	a 2.60

a Approximate.

Daily gage height, in feet, of Arkansas River at Santa Fe Avenue Bridge, Pueblo, Colorado, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.
1	0.40	0.30	0.45	0.20	0.60	1.20	1.35	0.35
2	.45	.20	.45	.20	.70	1.20	1.20	.35
3	.45	.30	.40	.20	.75	1.50	1.20	.30
4	.40	.40	.40	.30	.85	1.55	1.15	.30
5	.40	.40	.40	.25	.90	1.55	1.00	.35
6	.40	.40	.35	.20	.85	1.50	1.30	.30
7	.40	.50	.30	.20	1.00	1.55	1.35	.45
8	.40	.50	.30	.20	1.10	1.80	1.55	.45
9	.40	.50	.30	.20	1.15	1.80	1.60	.50
10	.40	.45	.30	.20	1.20	1.70	1.45	.45
11	.40	.45	.35	.25	1.00	1.80	1.50	.45
12	.40	.40	.40	.55	.90	1.85	1.50	.30
13	.40	.35	.30	.55	.90	1.80	3.20	.20
14	.35	.40	.30	.45	.95	1.85	2.70	.15
15	.30	.40	.30	.45	.90	2.05	2.20	.20
16	.30	.40	.30	.60	.90	2.10	1.90	.25
17	.30	.50	.30	.65	.95	2.25	2.05	.40
18	.35	.45	.30	.65	.80	2.50	1.70	.35
19	.40	.40	.30	.60	.75	2.70	1.35	.30
20	.35	.40	.30	.50	.65	2.80	1.05	.30
21	.35	.40	.30	.45	.65	2.80	1.05	.25
22	.25	.40	.30	.40	.60	2.55	1.00	.30
23	.15	.40	.35	.35	.60	2.45	1.00	.25
24	.20	.40	.30	.30	.50	2.40	.90	.20
25	.10	.40	.30	.30	.50	2.40	1.10	.25
26	.10	.35	.30	.30	.90	2.35	1.25	.25
27	.30	.45	.30	.30	.90	1.90	.95	.20
28	.25	.40	.30	.30	.75	1.60	.75	.....
29	.25	.....	.30	.55	.85	1.45	.50	.....
30	.40	.....	.30	.50	1.10	1.35	.45	.....
31	.30	.....	.20	.....	1.15	.....	.40	.....

Daily gage height, in feet, of Arkansas River at Main Street Bridge, Pueblo, Colorado, for 1898.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	0.50	—0.05	—0.35	0.34	0.37	17	2.10	0.95	0.15	0.26	0.30	0.37
2	.....	.40	+ .05	— .35	.34	.30	18	2.20	.40	.15	.26	.35	.51
3	.....	.40	— .10	— .40	.25	.25	19	1.50	.18	.10	.28	.29	.51
4	.....	.30	— .23	— .40	.25	.25	20	1.40	.18	.20	.32	.30	.50
5	.....	.20	— .18	— .43	.24	.25	21	1.15	.12	— .10	.32	.39	.47
6	.....	.20	— .21	— .44	.22	.31	22	1.10	.10	— .20	.32	.35	.45
7	.....	.50	— .38	— .38	.22	.40	23	.95	.10	— .20	.32	.32	.35
8	.....	.50	— .34	— .30	.25	.10	24	.85	.15	— .17	.32	.35	.34
9	.....	.58	— .21	— .20	.30	.11	25	.95	.15	— .14	.41	.38	.49
10	1.60	.65	— .11	— .10	.30	.27	26	1.30	.12	— .11	.42	.37	.49
11	1.30	.50	+ .15	— .13	.32	.30	27	.80	.06	— .12	.44	.32	.50
12	2.40	.43	.12	— .09	.20	.40	28	.80	.01	— .23	.45	.27	.48
13	4.45	.20	.21	.00	.30	.33	29	.68	.00	— .26	.40	.42	.49
14	3.20	.10	.12	.02	.34	.31	30	.58	.00	— .32	.45	.32	.47
15	3.30	.20	.19	.04	.34	.33	31	.50	—.04	.....	.37	.....	.45
16	2.00	.20	.18	.10	.32	.40							

Daily gage height, in feet, of Arkansas River at Nepesta, Colorado, for 1898.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	.....	2.80	3.30	3.20	3.00	2.60	2.40	3.20
2	.....	3.10	3.30	3.80	2.90	2.70	2.60	3.15
3	.....	3.00	3.30	3.70	2.80	2.60	2.70	3.15
4	.....	3.40	3.50	3.50	2.70	2.50	2.80	3.10
5	.....	3.10	3.60	3.40	2.60	2.40	2.80	3.10
6	.....	3.10	3.65	3.50	2.50	2.50	2.80	3.10
7	.....	3.10	3.50	3.70	3.05	2.50	2.90	3.00
8	.....	4.30	4.00	3.80	3.20	2.50	2.90	2.90
9	.....	6.00	4.50	4.40	3.30	2.55	2.90	2.90
10	.....	4.20	4.30	4.00	3.30	2.50	2.70	3.05
11	.....	4.00	4.00	3.80	3.20	2.70	2.60	3.05
12	.....	4.00	4.30	3.70	3.10	2.80	2.80	3.10
13	.....	3.60	4.30	4.00	2.60	2.90	2.80	3.10
14	.....	3.50	4.30	6.10	2.10	3.00	2.80	3.20
15	.....	3.40	5.70	5.10	2.80	3.00	2.80	3.15
16	.....	3.45	4.80	4.70	2.90	2.90	2.80	3.10

Daily gage height, in feet, of Arkansas River at Nepesta, Colorado, 1898—Cont'

Day.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
17	.....	3.50	4.80	4.40	2.80	2.90	2.80	3.10
18	.....	3.00	4.80	4.50	3.10	2.90	2.90	3.10
19	.....	3.60	4.80	4.00	3.10	2.90	3.00	3.10
20	.....	3.40	4.80	3.80	2.90	2.90	3.00	3.10
21	.....	3.40	4.70	3.50	2.80	2.90	3.00	3.10
22	.....	3.70	4.80	3.20	2.70	2.90	2.95	3.10
23	.....	3.20	4.80	3.00	3.35	2.90	3.00	3.10
24	.....	2.90	4.80	2.60	3.00	2.90	3.00	3.10
25	.....	2.70	4.50	2.20	2.90	2.90	3.00	3.00
26	2.60	2.50	4.40	3.90	2.90	2.90	3.00	3.00
27	2.55	4.00	4.20	3.70	2.80	3.00	3.10	3.00
28	2.50	3.10	4.60	3.10	3.00	2.80	3.10	3.00
29	2.70	3.10	3.80	3.20	2.80	2.80	3.10	2.90
30	2.80	3.30	3.50	3.10	2.90	2.80	3.20	2.90
31	.....	3.30	.....	3.00	2.60	.....	3.20	.....

Daily gage height, in feet, of Arkansas River at Rocky Ford, Colorado, for 1898

Day.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	0.90	0.72	1.20	1.02	0.91	1.00	0.74	0.72	1.19	0.81
2	.....	.93	.71	1.25	.95	.98	.93	.79	.70	1.18	.75
3	.....	.93	.82	1.32	1.04	1.35	.93	.69	.65	1.00	.60
4	.....	.98	.92	1.50	1.34	1.50	1.00	.65	.62	.95	.60
5	.....	.95	.79	1.50	1.48	1.40	.90	.60	.62	1.05	.60
6	.....	.92	.70	1.36	1.48	1.32	.81	.60	.60	.92	1.00
7	.....	.90	.70	1.50	1.45	1.35	.80	.55	.60	.91	1.00
8	.....	.92	.72	2.20	2.05	1.60	.96	.54	.65	.90	1.00
9	.....	.98	.70	2.80	2.15	2.80	1.18	.52	.70	.90	1.00
10	.....	.98	.60	2.10	2.25	1.74	1.13	.52	.68	1.18	1.00
11	.....	.98	.52	2.10	2.13	1.55	1.08	.58	.65	.98	1.00
12	.....	.92	.80	2.05	2.38	1.27	1.02	.71	.65	1.00	1.00
13	.....	.89	.97	1.70	2.35	1.55	.95	.75	.84	1.12	.80
14	.....	.89	.85	1.55	2.37	3.15	1.03	.87	.73	1.16	.70
15	.....	.95	.89	1.52	2.85	2.70	1.00	.95	.83	1.20	.70
16	.....	.88	.85	1.38	2.75	2.40	.80	.95	.90	1.20	.75
17	.....	.83	.90	1.33	2.62	2.23	.77	.98	.84	1.20	.70
18	.....	.87	.98	1.25	2.25	2.19	.80	.89	.85	1.22	.....
19	.....	.98	1.10	1.06	2.77	1.75	.83	.88	.98	1.20	.....
20	0.52	1.01	1.11	.90	2.85	1.50	.75	.84	1.00	1.19	.....
21	.42	1.01	1.04	1.60	2.90	1.28	.77	.83	1.03	1.20	.....
22	.30	.88	.98	1.22	2.75	1.20	.79	.80	.88	1.25	.....
23	.41	.80	.93	.94	2.50	1.00	.85	.80	.89	1.25	.....
24	.45	.80	.86	.80	2.40	.85	.78	.80	.94	1.30	.....
25	.45	.80	.81	.70	2.35	1.10	1.05	.82	1.00	1.30	.....
26	.54	.80	.80	3.20	2.15	1.18	.81	.90	1.00	1.20	.....
27	.70	.78	.72	2.02	2.00	1.25	.72	.82	1.05	.98	.....
28	.86	.75	.70	1.40	1.60	1.35	.81	.77	1.05	.80	.....
29	.....	.80	.71	1.25	1.43	1.18	.80	.75	1.05	.60	.....
30	.....	.79	.82	1.15	1.18	1.08	.79	.82	1.12	.74	.....
31	.....	.75	.....	1.15	.....	1.05	.75	.....	1.12	.....	.....

Daily gage height, in feet, of Arkansas River at Manzanola, Colorado, for 18

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Day.	May.	June.	July.	Aug.	Sept.	Oct.
1	.....	3.40	3.40	2.40	1.60	2.20	17	.....	4.40	4.40	2.20	2.50	2.40
2	.....	3.40	3.30	2.50	1.00	2.30	18	3.30	4.80	4.00	2.40	2.50	2.50
3	.....	3.50	3.50	2.30	.80	2.30	19	3.30	5.20	3.80	2.30	2.40	2.50
4	.....	3.90	3.40	2.30	.80	2.20	20	2.90	5.20	3.30	2.20	2.40	2.50
5	.....	3.80	3.50	2.20	.80	2.20	21	4.00	5.00	3.00	2.00	2.40	2.60
6	.....	3.70	3.40	2.00	.80	2.20	22	3.30	4.90	2.70	2.00	2.40	2.60
7	.....	3.50	3.40	2.00	2.00	2.20	23	3.20	4.70	2.50	1.90	2.50	.....
8	.....	4.30	4.20	2.60	2.00	2.20	24	2.90	4.60	2.40	1.90	2.50	.....
9	.....	4.00	5.50	2.50	1.90	2.30	25	3.10	4.40	2.50	3.00	2.40	.....
10	.....	4.40	3.90	2.40	1.90	2.30	26	4.55	4.40	3.00	2.80	2.30	.....
11	.....	4.40	4.00	2.40	2.00	2.30	27	4.20	4.30	3.60	2.00	2.30	.....
12	.....	3.70	4.20	2.40	2.20	1.90	28	3.40	4.00	3.00	1.90	2.20	.....
13	.....	3.50	5.20	2.30	2.50	2.40	29	3.30	3.80	2.70	1.90	2.20	.....
14	.....	4.30	6.00	2.30	2.70	2.50	30	3.30	3.50	2.40	1.80	2.20	.....
15	.....	4.00	5.00	2.30	2.80	2.60	31	3.50	.....	2.40	1.60	.....	.....
16	.....	4.40	4.60	2.30	2.80	2.60							

Daily gage height, in feet, of Purgatory River at Trinidad, Colorado, for 1898.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	3.90	4.00	3.95	3.95	3.50	3.50	3.50
2	3.90	3.95	3.80	3.90	3.55	3.50	3.50
3	3.90	3.90	3.90	3.80	3.50	3.50	3.50
4	3.95	4.00	4.35	4.10	3.50	3.40	3.50
5	4.00	3.90	4.00	4.00	3.50	3.40	3.50
6	4.20	3.90	3.90	3.90	3.50	3.40	3.50
7	4.10	4.00	3.90	4.30	3.50	3.40	3.50
8	4.35	4.00	3.90	4.30	3.50	3.40	3.50
9	4.25	4.00	3.95	4.25	3.50	3.40	3.50
10	4.20	4.05	3.90	4.10	4.00	3.40	3.50
11	4.20	4.05	3.85	4.00	4.50	3.40	3.50
12	4.10	4.00	3.90	3.85	4.50	3.45	3.50
13	4.15	4.10	4.45	3.75	4.50	3.45	3.50
14	4.10	4.30	4.10	3.70	3.50	3.45	3.50
15	4.10	4.05	4.10	3.70	3.50	3.45	3.50
16	4.00	4.05	4.00	3.75	3.50	3.55	3.50
17	4.00	4.00	4.00	3.80	3.50	3.50	3.50
18	3.90	4.35	3.95	3.75	3.50	3.50	3.50
19	3.90	4.50	3.80	3.75	3.50	3.55	3.50
20	3.90	4.40	4.15	3.65	3.50	3.60	3.50
21	3.90	4.35	3.90	3.70	3.50	3.55	3.50
22	3.90	4.25	3.80	3.70	3.50	3.50	3.45
23	3.85	4.20	3.80	3.90	3.50	3.50	3.50
24	3.80	4.20	4.35	3.90	3.50	3.50	3.50
25	3.80	4.10	4.05	3.70	3.50	3.50	3.45
26	3.95	4.00	3.90	3.60	3.50	3.50	3.50
27	3.90	4.00	3.85	3.60	3.50	3.50	3.50
28	3.90	3.85	3.70	3.60	3.50	3.45	3.50
29	3.90	3.80	3.70	3.60	3.50	3.40	3.50
30	3.90	3.80	3.70	3.60	3.50	3.45	3.50
31	4.00	.....	4.05	3.50	.....	3.50	.....

Daily gage height, in feet, of Purgatory River at J. J. Ranch, for 1898.

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Day.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	.....	2.20	.....	2.70	2.70	2.70	17	2.90	.....	2.90	2.70	3.00	.....
2	.....	2.20	.....	2.70	2.70	2.70	18	2.50	.....	3.00	2.70	3.00	.....
3	.....	.....	.....	2.70	2.70	2.70	19	2.50	.....	2.90	2.70	2.90	.....
4	.....	.....	.....	2.70	2.50	2.70	20	3.00	.....	2.90	2.70	2.70	.....
5	.....	.....	.....	2.70	2.50	2.70	21	3.50	.....	3.00	2.70	2.70	.....
6	.....	.....	.....	2.70	2.50	2.70	22	2.60	.....	3.00	2.70	2.70	.....
7	.....	.....	5.20	2.70	2.50	2.70	23	2.50	.....	3.00	2.70	2.70	.....
8	.....	.....	5.70	2.70	2.50	2.70	24	2.30	.....	3.00	2.70	2.70	.....
9	.....	.....	4.00	2.60	2.50	2.70	25	2.30	.....	3.00	2.70	2.70	.....
10	.....	.....	3.80	2.70	3.00	2.70	26	2.50	.....	2.30	2.70	2.70	.....
11	.....	.....	3.80	2.70	2.80	2.70	27	2.30	.....	3.00	2.70	2.70	.....
12	.....	.....	3.80	2.70	2.70	2.70	28	2.90	.....	2.70	2.70	2.70	.....
13	2.30	.....	3.00	2.70	2.50	.....	29	2.70	.....	2.70	2.70	2.70	.....
14	2.40	.....	3.30	3.70	2.80	.....	30	2.50	.....	2.70	2.70	2.70	.....
15	2.40	.....	3.40	2.70	2.80	.....	31	.....	.....	2.70	.....	2.70	.....
16	2.95	.....	2.90	2.70	3.00	.....							

Daily gage height, in feet, of Arkansas River at Las Animas, Colorado, for 1898.

Day.	May.	July.	Aug.	Sept.	Oct.	Nov.	Day.	May.	July.	Aug.	Sept.	Oct.	Nov.
1	.....	.....	3.10	2.40	2.30	2.90	17	2.80	.....	3.10	2.40	2.30	.....
2	.....	.....	2.80	2.40	2.30	2.90	18	.....	.....	2.80	2.40	2.30	.....
3	.....	.....	2.70	2.40	2.30	2.90	19	2.75	3.75	2.70	2.40	2.40	.....
4	.....	.....	2.80	2.40	2.30	3.00	20	.....	3.45	2.60	2.40	2.40	.....
5	.....	.....	2.70	2.40	2.30	3.00	21	2.80	3.20	2.60	2.40	2.40	.....
6	.....	.....	2.70	2.30	2.30	2.90	22	2.80	3.10	2.60	2.40	2.75	.....
7	.....	.....	2.80	2.30	2.30	3.00	23	2.80	3.00	2.50	2.40	2.80	.....
8	.....	.....	2.70	2.30	2.30	3.00	24	.....	3.00	2.50	2.40	2.80	.....
9	.....	.....	2.60	2.20	2.30	2.90	25	2.40	2.80	2.50	2.40	2.80	.....
10	.....	.....	2.60	2.30	2.30	2.90	26	2.40	2.70	2.50	2.40	2.90	.....
11	.....	.....	2.50	2.30	2.30	2.90	27	5.50	2.60	2.50	2.40	2.80	.....
12	.....	.....	2.50	2.40	2.30	3.00	28	3.20	2.60	2.50	2.30	2.80	.....
13	3.50	.....	2.50	2.50	2.30	.....	29	.....	2.60	2.50	2.30	2.70	.....
14	3.20	.....	2.50	2.50	2.30	.....	30	.....	2.90	2.50	2.30	2.90	.....
15	3.10	.....	2.50	2.50	2.30	.....	31	.....	3.00	2.50	.....	3.00	.....
16	3.30	.....	2.25	2.50	2.30	.....							

Daily gage height, in feet, of Arkansas River at Amity Canal head gate, for 18

Day.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.35	0.55	0.10	1.90	3.00	17	5.50	.60	.40	1.60	2.30
2	2.95	.40	.10	1.90	3.00	18	3.90	.60	.50	1.60	2.30
3	2.10	.30	.10	1.90	3.00	19	2.30	.50	.70	1.60	2.30
4	2.05	.25	.10	1.90	3.00	20	1.75	.40	.90	1.60	2.00
5	1.82	.20	.10	1.90	3.00	21	1.55	.40	.80	1.50	2.00
6	2.20	.15	.10	1.95	3.00	22	1.30	.40	.80	1.00	2.00
7	2.20	.10	.10	1.90	3.00	23	1.30	.40	1.10	2.90	2.00
8	2.40	.10	.20	2.00	2.55	24	2.30	.30	1.30	4.80	2.00
9	3.15	.10	.20	2.00	1.80	25	1.30	.30	1.50	5.00	2.00
10	2.75	.20	.20	2.00	1.90	26	1.15	.30	1.60	5.00	2.00
11	2.05	.20	.20	1.90	1.90	27	1.00	.30	1.70	5.00	2.00
12	1.85	.60	.20	2.00	2.00	28	1.65	.30	1.70	4.00	2.50
13	1.70	.80	.20	2.00	2.15	29	1.35	.20	1.50	3.50	2.50
14	1.60	.80	.20	2.00	2.30	30	1.05	.20	1.40	3.20	2.00
15	1.55	.70	.20	2.00	2.30	31	.80	.....	1.60	.....	2.00
16	1.45	.60	.40	1.90	2.30						

Daily gage height, in feet, of Arkansas River at Granada, Colorado, for 1898

Day.	July.	Aug.	Sept.	Oct.	Nov.	Day.	July.	Aug.	Sept.	Oct.	Nov.
1	.....	1.20	0.60	0.60	1.00	17	.....	0.60	0.60	0.80	0.60
2	.....	.80	.60	.40	.90	18	.....	1.60	.60	.60	.60
3	.....	.80	.80	.40	.90	19	.....	.80	.80	1.50	.60
4	.....	.60	.80	.40	.90	20	.....	.60	.70	1.50	.....
5	.....	.40	.80	.40	.90	21	.....	.40	.60	1.30	.....
6	.....	.40	.60	.40	.90	22	.....	.60	.60	1.30	.....
7	.....	.40	.60	.40	.90	23	.....	.60	.60	1.30	.....
8	.....	.40	.60	.40	.90	24	0.60	1.00	.60	1.30	.....
9	.....	.40	.60	.60	1.00	25	.60	.90	.60	1.00	.....
10	.....	.40	.80	.60	1.00	26	.80	.60	.60	1.00	.....
11	.....	.40	.80	.60	1.00	27	1.20	.40	.60	.80	.....
12	.....	.40	.80	.60	1.00	28	1.20	.40	.60	.80	.....
13	.....	.40	.60	.60	1.00	29	.80	1.00	.60	.80	.....
14	.....	.20	.60	.60	1.00	30	.60	.80	.60	.80	.....
15	.....	.20	.60	.60	1.00	31	1.00	.40	.....	1.00	.....
16	.....	.30	.60	.80	.60						

Daily gage height, in feet, of Arkansas River at Hutchinson, Kansas, for 189

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.50	2.10	1.95	1.60	2.55	3.50	3.20	1.90	1.30	1.50	1.30	1.60
2	1.50	2.10	1.90	1.60	2.80	3.60	2.90	1.85	1.20	1.50	1.30	1.55
3	1.50	2.20	1.90	1.60	2.30	3.40	2.90	1.75	1.20	1.50	1.30	1.50
4	1.50	2.30	1.90	1.60	2.20	2.70	2.80	1.75	1.20	1.45	1.30	1.60
5	1.50	2.30	1.90	1.60	2.20	2.60	2.80	1.70	1.20	1.40	1.30	1.60
6	1.50	2.30	1.90	1.70	2.20	2.55	2.80	1.60	1.20	1.40	1.30	1.40
7	1.50	2.40	1.90	1.70	2.20	2.50	2.65	2.05	1.20	1.40	1.30	1.55
8	1.50	2.40	1.90	1.65	2.20	2.70	2.55	2.05	1.20	1.40	1.30	1.50
9	1.60	2.40	1.90	1.60	2.20	2.70	2.45	2.00	1.10	1.40	1.30	1.60
10	1.75	2.55	1.90	1.60	2.10	2.60	2.35	1.90	1.10	1.45	1.30	1.50
11	2.00	2.85	1.90	1.60	2.10	2.60	2.25	1.90	1.35	1.45	1.30	1.50
12	2.00	2.75	1.90	1.60	2.10	2.60	2.20	1.90	1.40	1.40	1.30	1.50
13	2.15	2.70	1.90	1.60	2.00	2.65	2.15	1.90	1.40	1.40	1.30	1.50
14	2.30	2.55	1.85	1.65	2.00	3.80	2.05	1.85	1.40	1.40	1.30	1.60
15	2.40	2.40	1.80	1.60	2.00	3.70	1.90	1.75	1.35	1.30	1.30	1.60
16	2.40	2.40	1.80	1.60	2.00	3.60	2.55	1.70	1.40	1.35	1.30	1.60
17	2.50	2.40	1.80	1.65	2.00	3.55	2.85	1.65	1.50	1.50	1.30	1.60
18	2.60	2.40	1.85	1.70	2.15	3.50	2.80	1.60	1.50	1.40	1.30	1.60
19	2.60	2.30	1.80	1.75	2.15	3.40	2.65	1.55	1.40	1.40	1.30	2.25
20	2.50	2.20	1.75	1.90	2.00	3.35	2.45	1.50	1.40	1.40	1.30	2.50
21	2.50	2.10	1.70	2.00	2.00	3.30	2.35	1.50	1.50	1.40	1.30	2.35
22	2.35	2.10	1.70	2.00	2.00	3.30	2.25	1.50	1.75	1.40	1.30	2.20
23	2.35	2.10	1.70	2.00	2.00	3.45	2.05	1.50	2.05	1.40	1.40	2.00
24	2.20	2.00	1.70	1.90	2.00	3.25	2.00	1.50	2.30	1.40	1.45	1.85
25	2.20	2.00	1.65	1.90	2.00	3.05	2.00	1.50	2.05	1.40	1.55	1.80
26	2.20	2.00	1.60	1.80	2.05	3.10	2.00	1.45	1.95	1.40	1.60	1.80
27	2.20	2.00	1.60	1.80	2.15	3.35	2.00	1.40	1.80	1.40	1.60	1.70
28	2.20	2.00	1.60	1.70	2.20	3.40	2.00	1.40	1.75	1.40	1.70	1.70
29	2.30	.....	1.60	1.70	2.70	3.30	1.95	1.40	1.60	1.40	1.65	1.70
30	2.10	.....	1.60	2.40	3.10	3.20	1.90	1.35	1.60	1.30	1.70	1.70
31	2.10	.....	1.60	.....	3.30	.....	1.90	1.30	.....	1.30	.....	1.70

Daily gage height, in feet, of [illegible] River at Liberty, Kansas, [illegible]

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1.90	.....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.....	2.40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.90	.....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.....	2.40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.90	.....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.....	.....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.90	2.30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.....	.....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.....	2.30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.90	.....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.....	16.30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.90	5.30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.....	.....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2.30	3.30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.....	.....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.....	3.30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2.30	.....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.....	3.10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2.30	.....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.....	.....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2.20	2.70	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.....	.....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.....	2.60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2.40	.....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.....	2.50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4.40	.....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.....	.....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2.40	2.30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.....	.....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.....	.....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2.40	.....	[illegible]	.....	[illegible]	.....	[illegible]	[illegible]	.....	[illegible]	.....	[illegible]

Daily gage height, in feet, of Neosho River at Iola, Kansas, [illegible]

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1.90	1.95	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.90	1.95	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.90	1.95	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.90	1.90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.90	1.95	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.90	1.90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.90	1.90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.90	1.95	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.90	1.95	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.90	1.95	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.90	2.00

List of discharge measurements, 1898.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	ch
				Feet.	*Se*
July 30	Arkansas River	Granite, Colo	A. L. Fellows	3.50	
Aug. 26	do	do	do	3.40	
Oct. 26	do	do	do	3.30	
Apr. 27	do	Salida, Colo	do	1.10	
May 20	do	do	do	1.10	
June 25	do	do	do	3.10	
July 29	do	do	do	1.25	
Aug. 26	do	do	do	.90	
Oct. 26	do	do	do	.80	
May 21	do	Canyon, Colo	do	3.05	
June 25	do	do	do	4.82	
July 28	do	do	do	3.05	
Oct. 27	do	do	do	2.60	
Apr. 5	do	Pueblo, Colo	P. J. Preston	.27	
Apr. 29	do	do	A. L. Fellows	.60	
May 5	do	do	C. W. Beach	.90	
May 30	do	do	do	1.00	
June 3	do	do	do	1.40	
June 9	do	do	A. L. Fellows	1.80	
June 14	do	do	C. W. Beach	1.90	
July 8	do	do	do	1.63	
July 26	do	do	A. L. Fellows	.85	
July 28	do	do	C. W. Beach	.81	
Aug. 2	do	do	do	.45	
Aug. 11	do	do	do	.50	
Aug. 20	do	do	R. W. Hawley	.15	
Aug. 30	do	do	A. L. Fellows	.00	
Oct. 20	do	do	C. W. Beach	.20	
Oct. 29	do	do	A. L. Fellows	.40	
Nov. 3	do	do	C. W. Beach	.30	
Apr. 27	do	Nepesta, Colo	P. J. Preston	2.55	
May 6	do	do	C. W. Beach	3.05	
May 10	do	do	do	4.25	
June 6	do	do	do	3.43	
July 28	do	do	do	3.25	
Aug. 20	do	do	do	2.85	
Nov. 6	do	do	do	2.93	
Apr. 17	do	Rocky Ford, Colo	P. J. Preston	.90	
May 27	do	do	C. W. Beach	1.83	
May 18	do	Manzanola, Colo	do	3.25	
Sept. 15	do	do	do	2.38	
Apr. 28	Purgatory River	Trinidad, Colo	A. L. Fellows	3.90	
July 27	do	do	do	3.90	
Aug. 6	do	do	do	3.76	
Aug. 29	do	do	C. W. Beach	3.60	
Oct. 28	do	do	A. L. Fellows	3.40	
June 13	do	J. J. Ranch, Colo	do	2.30	
Aug. 5	do	do	do	3.65	
May 12	do	2 miles east of Las Animas, Colo.	C. W. Beach	1.50	
May 20	do	do	do	1.17	
Feb. 14	Arkansas River	Hutchinson, Kans.	W. G. Russell	2.55	
Mar. 1	do	do	do	1.90	
Apr. 26	do	do	do	1.85	
May 5	do	do	do	2.20	
May 25	do	do	do	2.00	
May 31	do	do	do	3.35	
June 1	do	do	do	3.50	
Sept. 15	do	do	do	1.30	
Oct. 25	do	do	do	1.40	
Mar. 24	Verdigris River	Liberty, Kans	E. C. Murphy	4.00	
Mar. 25	do	do	do	3.80	
May 19	do	do	do	9.70	
May 20	do	do	do	14.40	
July 12	do	do	do	2.80	
Mar. 24	Neosho River	Iola, Kans	do	2.80	
May 19	do	do	do	5.50	
May 20	do	do	do	10.60	1
July 11	do	do	do	2.85	

Rating tables.

Granite.		Salida.		Canyon.		Pueblo.		Nepesta. *a*		Nepesta. *b*	
Gage height.	Discharge	Gage height.	Discharge.	Gage height.	Discharge	Gage height.	Discharge.	Gage height	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
2.80	8	0.6	100	2.0	135	−0.4	38	2.0	168	2.1	1.7
2.85	10	.7	169	2.1	160	− .3	54	2.1	200	2.2	136
2.90	12	.8	241	2.2	186	− .2	75	2.2	234	2.3	147
2.95	14	.9	314	2.3	213	− .1	102	2.3	270	2.4	160
3.00	17	1.0	387	2.4	242	.0	136	2.4	308	2.5	175
3.05	20	1.1	460	2.5	276	.2	232	2.5	350	2.6	192
3.10	24	.....	.....	2.6	316	.4	380	2.6	396	2.7	212
3.15	35	.....	.....	2.7	360	.6	568	2.7	447	2.8	236
3.20	47	.....	.....	2.8	408	.8	780	2.8	504	2.9	260
3.25	60	.....	.....	2.9	476	1.0	1,006	2.9	568	3.0	294
3.30	75	.....	.....	3.0	560	1.2	1,258	3.0	641	3.2	511
3.35	93	.....	.....	3.1	682	1.4	1,512	3.2	817	3.4	759
3.40	112	.....	.....	3.2	807	1.6	1,766	3.4	1,025	3.6	1,007
3.45	131	.....	.....	3.3	932	1.8	2,020	3.6	1,250	3.8	1,255
3.50	151	.....	.....	3.4	1,057	2.0	2,274	3.8	1,480	4.0	1,503
3.55	171	.....	.....	3.5	1,182	2.5	2,909	4.0	1,710	4.2	1,751
.....	.....	.....	.....	3.6	1,307	3.0	3,544	4.2	1,940	4.4	2,000
.....	.....	.....	.....	3.7	1,432	3.5	4,179	4.4	2,170	4.6	2,250
.....	.....	.....	.....	3.8	1,557	4.0	4,814	4.6	2,400	4.8	2,500
.....	.....	.....	.....	3.9	1,682	4.5	5,449	4.8	2,630	5.0	2,750
.....	.....	.....	.....	4.0	1,807	5.0	6,084	5.0	2,860	5.2	3,000
.....	.....	.....	.....	4.1	1,932	5.5	6,719	5.2	3,090	5.4	3,250
.....	.....	.....	.....	4.2	2,057	6.0	7,354	5.4	3,320	5.6	3,500
.....	.....	.....	.....	4.3	2,182	6.5	7,989	5.6	3,550	5.8	3,750
.....	.....	.....	.....	4.4	2,307	7.0	8,624	5.8	3,780	6.0	4,000
.....	.....	.....	.....	4.5	2,432	7.5	9,259	6.0	4,010	6.2	4,250
.....	.....	.....	.....	4.6	2,557	8.0	9,894	.....	.....	.....	.....
.....	.....	.....	.....	4.7	2,682	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	4.8	2,807	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	4.9	2,932	.....	.....	.....	.....	.....	.....

Rocky Ford.		Trinidad.		Amity Canal.		Hutchinson.		Liberty.		Iola.	
Gage height.	Discharge.	Gage height.	Discharge	Gage height.	Discharge.	Gage height.	Discharge.	Gage height	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec. ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
0.3	34	3.4	31	0.0	0	1.1	4	.....	.....	1.8	1
.4	48	3.5	42	.1	6	1.2	10	1.5	0	1.9	25
.5	64	3.6	58	.2	11	1.3	18	2.0	20	2.0	50
.6	84	3.7	81	.3	17	1.4	32	2.5	87	2.2	105
.7	108	3.8	109	.4	23	1.5	44	3.0	256	2.4	170
.8	150	3.9	157	.5	30	1.6	60	3.5	501	2.6	245
.9	237	4.0	230	.6	38	1.7	82	4.0	770	2.8	340
1.0	393	4.1	335	.7	47	1.8	110	4.5	1,073	3.0	455
1.1	550	4.2	492	.8	56	1.9	140	5.0	1,400	3.2	590
1.2	706	4.3	752	.9	66	2.0	188	5.5	1,760	3.4	745
1.3	862	4.4	1,012	1.0	77	2.1	248	6.0	2,160	3.6	920
1.4	1,019	4.5	1,282	1.2	100	2.2	325	7.0	2,980	3.8	1,115
1.5	1,175	.....	.....	1.4	125	2.3	420	8.0	3,800	4.0	1,330
1.6	1,331	.....	.....	1.6	151	2.4	540	9.0	4,620	4.2	1,565
1.7	1,487	.....	.....	1.8	179	2.5	645	10.0	5,440	4.4	1,715
1.8	1,644	.....	.....	2.0	207	2.6	765	11.0	6,260	4.6	1,980
1.9	1,800	.....	.....	2.2	234	2.7	885	12.0	7,080	4.8	2,250
2.0	1,956	.....	.....	2.4	260	2.8	1,000	13.0	7,900	5.0	2,520
2.1	2,113	.....	.....	2.6	284	2.9	1,120	14.0	8,720	6.0	4,150
2.2	2,269	.....	.....	2.8	306	3.0	1,245	15.0	9,540	7.0	6,200
2.3	2,425	.....	.....	3.0	328	3.1	1,385	16.0	10,360	8.0	8,500
2.4	2,581	.....	.....	3.2	352	3.2	1,525	17.0	11,120	9.0	11,200
2.5	2,738	.....	.....	3.4	377	3.3	1,690	18.0	12,150	10.0	14,250
2.6	2,894	.....	.....	3.6	402	3.4	1,885	19.0	13,250	11.0	17,350
2.7	3,050	.....	.....	3.8	430	3.5	2,106	20.0	14,470	12.0	20,450
2.8	3,206	.....	.....	4.0	460	3.6	2,310	21.0	15,890	13.0	23,550
2.9	3,363	.....	.....	4.2	490	.....	.....	22.0	17,370	14.0	26,650
3.0	3,519	.....	.....	4.4	520	.....	.....	23.0	18,850	15.0	29,750
3.1	3,676	.....	.....	4.6	560	.....	.....	24.0	20,330	16.0	32,850
3.2	3,832	.....	.....	4.8	580	.....	.....	.....	.....	17.0	35,950

a Applicable from April 26 to July 14, 1898.
b Applicable from July 15 to November 30, 1898.

WESTERN GULF DRAINAGE.

DESCRIPTION OF RIVER STATIONS.

Dallas station on Trinity River.—This is located at a point 3 miles north of the court-house. It was established by Prof. Thomas U. Taylor on October 1, 1898. The observer is J. M. Bassett, engineer at the Turtle Creek pump house. Observations are made at 6 a. m. and 6 p. m. upon a gage in the well at the pump house. The height of water is indicated by a pointer which slides up and down. The well is connected with the river by a pipe. The top of the well is 99 feet above the city datum. Measurements of discharge are made by wading. The channel is nearly straight both above and below the point of measurement; the right bank is high, and the left bank is low and liable to overflow. The bed of the stream is of gravel, and shifting.

Waco station on Brazos River.—This station is at the Austin Street Bridge, northwest of Waco, being about 75 miles above the station at Lewis. The observer is C. E. Rogers, a watchman, who takes readings at 6 a. m. and 6 p. m. The gage is inclined, the channel straight, the banks high, but the bed of the stream is of shifting sand. Measurements of discharge have been made under the suspension bridge, above the railroad bridge. Under the former, at low water, is a sand bar, which does not affect, however, the reliability of the measurements, as there are then two distinct channels. This is the condition during the greater part of the year.

Lewis station on Brazos River.—This station is about 1¼ miles southwest of Lewis, Texas, at the International and Great Northern Railroad bridge. The observer, J. M. Proctor, post-office, Hearne, Texas, is a bridge watchman, and takes readings at 6 a. m. and 6 p. m. The gage is vertical, fastened to a post of the bridge. The channel is nearly straight, and the water moves with moderate rapidity. The banks are high and the bed of the stream sandy. Since the establishment of the station at Waco this locality has less importance.

Austin station on Colorado River.—Measurements of Colorado River of Texas are made at two points near Austin. The first of these (Station No. 2) is at the Lake McDonald dam, 3 miles west of the city, and the other at a point above the Congress Avenue Bridge, south of the city. Observations of height of water in Lake McDonald above the dam are made by means of a float placed above the bulkhead of the power house and between it and the breakwater. This float is connected by wire to a suitable index in the power house. The table on page 122 gives the average daily reading thus obtained. The values are expressed in plus and minus, according as the water surface is above or below the crest. A similar reading has been kept since September 1, 1895. A measurement above the head of the lake was made on January 8, 1898, at Sulphur Hollow. The water from the tailrace of the power house flows along in front of the toe of the dam

and parallel with it. When the water is below the crest the flow in the tailrace has been determined to be fairly uniform. Measurements of discharge are made from a temporary bridge placed across this race. The following measurements give the flow: January 5, 1898, 226 second-feet; January 6, 230; January 7, 233; January 13, 234; December 21, 298; December 22, 296.

The observations south of the city are made on a vertical gage attached to a bath house. The observer is W. Peterson. The bench mark is on the first flange above the crib work of the north pier of the highway bridge. Its height is 4.78 feet above the zero of the gage. Measurements of discharge are made at a narrow place in the river, about one-fourth of a mile above.

New Braunfels station on Guadalupe River.—This station is about 1 mile east of the town of New Braunfels, Texas, near the highway bridge below the International and Great Northern Railroad bridge. Observations were begun on March 13, 1898. The observer is G. Behnsch, a storekeeper living about 200 yards from the gage. The readings are made at 8 a. m. and 6 p. m. The gage is an inclined rod, marked to vertical feet and tenths. Discharge measurements are made at a point above the railroad bridge, where the river is divided into two channels by an island. The channels are nearly straight, the bed of the stream rocky, and the results are believed to be reliable. The flow is so nearly constant that observations through a year are believed to be sufficient for all purposes. The following discharge measurements have been made by Prof. Thomas U. Taylor: March 12, 1898, gage height 2.00, discharge, 350 second-feet. On December 20, 1898, gage height 1.90, the discharge of the Guadalupe above the junction of Comal and Guadalupe, 1½ miles north of the city, just below the cemetery crossing, was 44 second-feet.

Pecos station on Pecos River.—Observations of height of Pecos River have been made at a point 6 miles above the town of Pecos, on the Texas and Pacific Railway. The observer is Willard H. Denis, water master, and the time of observations 6 a. m. and 6 p. m. Readings are made at two points, one of these being in the river itself, under the flume of the Margueretta Canal, and the other in the flume which carries the water across Pecos River from the right-hand side to the left, as shown on page 62 of Paper No. 13, where is given a view of the flume. The channel at this point is nearly straight, the water sluggish, the banks high, and the bottom sandy and shifting.

High Bridge station on Pecos River.—This station was established on March 17, 1898, and maintained until December 3, 1898, being discontinued on account of the difficulty of access. It is located at the Pecos viaduct of the Southern Pacific Company. This viaduct is 2,180 feet long and the base of the rails are 321 feet above low water. The observer is J. H. King, post-office, Lozier, Pecos County, Texas. He is section foreman on the railroad, and makes observations

at 6 p. m. The gage is vertical, fastened to the bridge pier. T channel is straight and the banks high and rocky. The first me urement, that made March 16, 1898, at a gage height of 1.00, gav discharge of 388 second-feet.

Del Norte station on Rio Grande.—Described on page 127 of Pa No. 16. Results for 1897 given on page 381 of the Nineteenth Ann Report, Part IV. Observations are made on alternate days.

Embudo station on Rio Grande.—Described on page 128 of Pa No. 16. Results for 1897 given on page 384 of the Nineteenth Ann Report, Part IV.

Rio Grande station on Rio Grande.—Described on page 130 Paper No. 16. Results for 1897 given on page 386 of the Nineteen Annual Report, Part IV.

San Marcial station on Rio Grande.—Described on page 131 Paper No. 16. Results for 1897 given on page 387 of the Nineteen Annual Report, Part IV.

El Paso station on Rio Grande.—Described on page 132 of Pa No. 16; results given on page 389 of the Nineteenth Annual Repo Part IV. Work at this locality has been carried on by T. M. Co chesne, under the direction of Mr. W. W. Follett, consulting en neer, International (Water) Boundary Commission. A large numb of measurements were made during 1898, as shown in the followi list. During the months of October and November the water was low (probably not more than 2 to 3 second-feet) that the meter co not be used during that time.

List of discharge measurements on Rio Grande at El Paso, Texas.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1898.	*Sec.-ft.*	*Sec.-ft.*	1898.	*Sec.-ft.*	*Sec.-ft.*	1898.	*Sec.-ft.*	*Sec.-ft.*
Jan. 3	7.00	458	May 2	11.00	5,218	July 27	8.40	1,891
Jan. 5	7.20	471	May 3	11.40	6,059	July 29	8.00	1,366
Jan. 7	7.60	640	May 5	11.00	4,773	Aug. 3	7.30	813
Jan. 10	7.50	630	May 7	10.40	3,623	Aug. 6	7.20	637
Jan. 12	7.40	513	May 9	9.50	2,547	Aug. 8	7.10	515
Jan. 14	7.60	676	May 14	9.00	1,184	Aug. 11	7.60	803
Jan. 15	7.30	456	May 17	9.10	1,769	Aug. 13	8.50	2,026
Jan. 17	7.30	474	May 19	9.10	1,884	Aug. 16	7.30	649
Jan. 19	7.90	703	May 23	8.80	1,455	Aug. 18	6.70	353
Jan. 22	7.30	440	May 25	8.40	1,071	Aug. 20	6.40	249
Jan. 25	7.30	434	May 27	8.30	958	Aug. 22	6.00	160
Jan. 28	7.10	400	May 30	7.60	627	Aug. 25	5.90	122
Jan. 29	7.00	361	June 2	7.50	522	Aug. 27	5.70	111
Jan. 31	6.70	207	June 4	7.80	605	Aug. 29	6.30	253
Feb. 2	7.10	404	June 6	8.50	1,137	Aug. 31	5.80	122
Feb. 4	8.10	862	June 7	9.50	2,640	Sept. 3	5.40	64
Mar. 2	7.40	361	June 9	9.00	1,961	Sept. 5	5.30	41
Mar. 20	7.40	405	June 11	10.10	3,080	Sept. 7	5.10	23
Mar. 22	7.10	280	June 20	8.90	1,344	Sept. 10	5.20	25
Mar. 24	6.80	192	June 22	8.70	1,288	Sept. 12	5.00	18
Mar. 27	6.60	120	June 24	8.80	1,484	Sept. 15	5.90	185
Mar. 28	6.50	136	June 27	9.80	2,674	Sept. 17	5.50	84
Mar. 31	6.30	99	June 30	9.60	2,153	Sept. 19	5.30	46
Apr. 1	6.30	95	July 2	9.60	1,926	Sept. 21	5.10	30
Apr. 3	6.10	63	July 6	10.40	3,629	Sept. 24	4.70	9
Apr. 16	7.00	266	July 7	11.00	3,860	Dec. 6	5.40	79
Apr. 18	8.80	1,693	July 9	9.50	1,965	Dec. 19	5.50	96
Apr. 21	9.80	2,461	July 12	9.90	3,105	Dec. 21	5.40	75
Apr. 22	10.30	3,093	July 20	13.60	9,791	Dec. 24	5.40	67
Apr. 23	10.50	3,634	July 23	10.00	3,898	Dec. 27	6.10	196
Apr. 29	10.70	4,443	July 25	8.80	2,920	Dec. 29	5.80	125

TABLES OF DAILY GAGE HEIGHT.

Daily gage height, in feet, of Trinity River at Dallas, Texas, for 1898.

Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.
1	55.85	54.50	55.80	12	55.15	54.00	54.85	23	55.15	53.00	58.10
2	55.50	54.40	55.75	13	54.85	54.10	54.70	24	55.00	52.90	57.65
3	55.45	54.30	55.55	14	54.65	54.00	54.65	25	54.85	52.85	57.30
4	55.20	54.30	55.45	15	54.50	53.90	54.90	26	54.75	58.20	56.45
5	55.35	54.30	55.25	16	54.55	54.00	55.00	27	54.95	57.15	56.40
6	57.25	54.15	55.10	17	54.45	53.90	55.05	28	54.75	56.60	56.20
7	56.30	54.10	55.10	18	54.30	53.90	57.40	29	54.55	56.25	55.95
8	55.75	54.00	55.20	19	54.35	53.75	62.35	30	54.80	56.05	55.80
9	55.45	53.90	55.20	20	54.60	53.70	65.60	31	54.65	.....	55.65
10	55.35	54.00	55.15	21	54.90	53.60	58.95				
11	55.15	54.00	55.05	22	55.20	53.15	58.35				

Daily gage height, in feet, of Brazos River at Waco, Texas, for 1898.

Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.
1	.....	4.40	2.30	2.20	12	.....	2.80	2.60	2.30	23	2.70	2.80	2.20	2.90
2	.....	4.10	2.30	2.20	13	.....	2.80	2.50	2.30	24	2.70	2.80	2.20	2.80
3	.....	3.70	2.30	2.20	14	2.70	2.60	2.40	2.30	25	2.70	2.70	2.30	2.60
4	.....	3.60	2.30	2.20	15	2.70	2.60	2.40	2.30	26	6.50	2.50	2.40	2.50
5	.....	3.50	2.40	2.30	16	2.70	2.50	2.30	2.40	27	5.60	2.50	2.40	2.50
6	.....	3.50	2.30	2.30	17	2.70	2.50	2.30	2.40	28	5.10	2.50	2.40	2.50
7	.....	3.90	2.20	2.20	18	2.70	3.20	2.30	2.50	29	4.90	2.50	2.30	2.50
8	.....	3.30	2.20	2.20	19	2.70	3.30	2.20	3.80	30	4.70	2.40	2.30	2.50
9	.....	3.20	2.40	2.20	20	2.70	3.10	2.20	3.30	31	.....	2.40	.....	2.50
10	.....	3.10	2.50	2.30	21	2.70	2.90	2.40	3.00					
11	.....	3.10	2.50	2.30	22	2.70	2.70	2.30	2.90					

Daily gage height, in feet, of Brazos River at Lewis, Texas, for 1898.

Day.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	7.30	7.75	6.70	7.45	11.90	7.85	8.35	7.35	4.40	4.15
2	.....	7.10	7.95	6.70	7.40	10.40	8.00	9.60	7.00	4.35	4.10
3	.....	7.25	8.30	6.45	7.80	9.75	7.35	9.00	6.70	4.30	4.10
4	.....	7.50	8.55	6.40	8.90	8.80	6.95	8.15	6.45	4.40	4.10
5	.....	7.50	8.75	8.30	7.95	8.80	6.60	7.60	6.00	4.30	4.00
6	.....	7.50	9.30	8.10	7.50	8.45	6.40	7.00	6.00	4.50	4.10
7	.....	7.50	9.55	7.85	7.80	9.50	6.30	6.85	6.10	4.40	4.10
8	.....	7.55	8.55	7.95	9.40	9.00	6.10	6.40	5.90	4.25	4.10
9	.....	7.65	7.70	8.35	9.60	8.15	6.55	5.95	5.80	4.00	4.10
10	.....	7.85	7.45	8.65	8.65	8.00	8.85	5.70	5.60	4.05	4.10
11	.....	7.90	7.75	8.60	9.40	7.65	8.30	5.50	5.40	4.10	4.10
12	.....	7.70	8.20	8.15	11.25	7.20	7.95	5.45	5.30	4.10	4.10
13	.....	7.85	9.80	10.55	17.45	9.20	7.70	5.30	5.15	4.15	4.10
14	.....	9.20	10.75	10.55	20.40	8.70	7.20	5.15	5.00	4.20	4.10
15	.....	9.30	9.25	9.30	17.15	8.15	6.80	5.00	5.05	4.20	4.00
16	.....	8.65	11.00	8.60	16.05	8.45	6.60	5.05	4.90	4.20	4.00
17	.....	8.00	8.55	8.15	13.95	11.40	7.05	5.05	4.60	4.15	4.10
18	.....	7.75	9.25	7.95	13.65	10.10	7.05	4.95	4.60	4.15	5.20
19	.....	7.20	21.20	7.90	13.80	9.20	6.70	4.90	4.75	4.20	6.10
20	.....	7.55	14.00	7.90	15.00	8.70	6.25	4.85	5.15	4.20	6.55
21	.....	7.30	12.10	7.80	16.20	8.20	6.05	4.80	6.00	4.20	6.15
22	7.05	7.45	11.50	8.30	14.10	7.65	5.75	4.80	5.65	4.10	5.65
23	7.50	7.40	11.00	8.90	12.75	11.00	5.60	4.75	5.45	4.10	5.50
24	7.25	7.15	9.35	8.40	12.15	10.05	5.55	4.60	5.00	4.10	5.15
25	7.05	7.15	8.45	11.45	11.25	9.35	5.35	4.65	4.90	4.10	5.00
26	6.90	7.35	7.90	10.50	10.55	8.75	5.25	4.70	4.75	4.15	4.85
27	6.90	7.60	7.50	9.80	9.85	8.45	5.40	7.85	4.60	4.10	4.70
28	6.80	7.85	7.25	9.60	9.20	8.90	6.45	8.90	4.45	4.10	4.50
29	6.70	7.85	7.15	9.10	10.10	9.70	6.45	8.10	4.35	4.10	4.50
30	.....	8.45	6.95	8.45	11.20	8.35	6.35	7.45	4.30	4.15	4.45
31	.....	8.00	.....	7.85	.....	7.75	6.40	.....	4.35	.....	4.40

Daily gage height, in feet, on crest of dam of Colorado River at Austin, Texas, for 1895.

Day.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	0.45	0.65	0.30	0.30	17	.30	.25	.30	.30	.25
2	.....	.40	.50	.30	.30	18	.30	.25	.30	.30	.20
3	.....	.40	.90	.40	.30	19	.30	.25	.30	.30	.20
4	.....	.40	.85	.20	.30	20	.30	.20	.25	.40	.30
5	.....	.50	.70	.20	.25	21	.30	.15	.25	.40	.30
6	.....	.50	.60	.20	.25	22	.40	.10	.25	.60	.20
7	.....	.45	.55	.20	.25	23	1.20	.15	.25	.80	.35
8	.....	.40	.50	.20	.20	24	1.40	.10	.25	1.00	.40
9	.....	.40	.50	.20	.20	25	1.00	.60	.25	.80	.40
10	.....	.35	.45	.30	.30	26	.80	.50	.25	.60	.35
11	.....	.35	.45	.50	.20	27	.40	.25	.20	.40	.40
12	.....	.35	.40	.60	.20	28	.45	.25	.20	.30	.45
13	0.40	.40	.35	1.00	.25	29	.50	.40	.20	.30	.55
14	.30	.40	.35	.50	.25	30	.50	.80	.25	.40	.55
15	.30	.35	.35	.30	.25	31	.45	.....	.25	.....	.50
16	.30	.25	.30	.30	.25						

Daily gage height, in feet, on crest of dam of Colorado River at Austin, Texas, for 1896.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	0.50	0.90	0.90	0.30	0.50	−0.50	−5.70	0.15	0.30	1.30	1.20	0.30
2	.50	2.20	.80	.10	.45	−.60	−4.00	.10	.30	1.20	.90	.30
3	.45	1.80	.70	.20	.40	−.70	−2.20	.10	.30	1.00	.90	.30
4	.40	1.40	.60	.30	.35	−.80	−1.00	.05	.25	.80	.80	.30
5	.30	1.20	.60	.30	.30	−1.00	−.60	.00	.20	.50	.70	.30
6	.30	1.00	.60	.40	.30	−1.15	−.20	−.10	.15	.40	.70	.30
7	.30	.80	.60	.15	.25	−1.35	+.50	−.30	.10	.40	.60	.30
8	.30	.80	.60	.90	.40	−1.50	.60	−.40	.05	.30	.40	.40
9	.30	.70	.60	.80	.35	−1.80	.60	−.50	.00	.30	.40	.40
10	.30	.60	.70	.70	.30	−2.00	.50	−.60	−.05	.30	.40	.40
11	.30	.50	.60	.70	.25	−2.20	.45	−.80	−.15	.30	.50	.40
12	.30	.70	.70	1.30	.20	−2.40	.45	−1.00	−.25	.30	.50	.40
13	.30	.60	.70	1.20	.20	−2.60	.50	−1.05	−.35	.40	.45	.40
14	.30	.50	.60	1.20	.20	−2.80	.90	−1.15	−.45	.50	.45	.35
15	.30	.50	.60	1.20	.20	−3.00	2.60	−1.30	−.50	.60	.45	.35
16	.30	.60	.50	1.20	.20	−3.20	2.50	−1.40	−.60	.50	.40	.35
17	.30	.55	.50	1.10	.20	−3.30	2.00	−1.50	−.70	.40	.40	.30
18	.25	.50	.50	.90	.20	−3.50	1.20	−1.90	−.90	.40	.30	.30
19	.25	.45	.50	.60	.20	−3.60	1.00	−2.05	−1.00	1.00	.30	.30
20	.35	.40	.50	.70	.20	−3.70	.90	−2.20	−1.10	1.60	.30	.30
21	.35	.40	.50	.70	.20	−3.80	.80	−2.50	−1.30	1.80	.35	.30
22	.35	.40	.50	.70	.20	−4.00	.75	−2.60	−1.50	1.60	.35	.30
23	.35	.40	.50	.70	.15	−4.20	.70	−2.80	+2.50	2.00	.45	.30
24	.35	1.00	.50	.70	.10	−4.30	.60	−3.10	1.60	3.00	.35	.25
25	.30	1.20	.50	.60	.05	−4.50	.35	−.20	1.10	3.00	.35	.25
26	.30	1.10	.50	.70	.05	−4.80	.30	−1.50	2.70	2.60	.35	.25
27	.30	1.10	.50	.70	.00	−5.00	.20	1.00	2.60	2.00	.35	.25
28	.30	1.00	.40	.60	−.10	−5.20	.20	.60	2.00	1.60	.35	.25
29	.25	1.00	.30	.60	−.20	−5.40	.20	.50	1.80	1.60	.25	.30
30	.35	.....	.30	.50	−.30	−5.60	.15	.40	1.80	2.00	.25	.40
31	.90	.....	.30	.....	−.40	.....	.15	.....	.....	1.60	.....	.....

gage height, in feet, on crest of dam of Colorado River at Austin, Texas, for 1897.

ay.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	0.80	0.40	0.25	1.05	0.70	0.35	0.25	0.20	0.30	—0.03	0.50	—2.00
2	2.20	.30	.23	.90	.80	1.10	.20	.18	.25	— .25	.25	—2.40
3	2.00	.30	.23	.80	.70	1.10	.08	.20	.18	— .30	.15	—2.40
4	1.40	.30	.23	.70	.60	1.00	.00	.20	.20	— .35	.12	—2.40
5	1.00	.30	.23	.60	.50	1.20	— .05	.20	.20	— .50	.12	—2.40
6	.80	.40	.23	.50	.50	1.40	— .15	.20	.30	— .65	.12	—2.40
7	.80	.30	.25	.60	.60	1.00	— .28	.18	.35	— .75	.12	—2.40
8	.80	.30	.23	.95	.60	1.35	— .40	.08	.33	— .85	.17	—2.50
9	.60	.30	.23	.90	1.45	1.00	— .65	.00	.20	— .95	.05	—2.60
10	.60	.30	.23	.98	1.93	.83	— .80	— .05	.15	—1.02	.01	—2.60
11	.50	.35	.23	.85	1.40	.73	— .90	— .20	.10	—1.05	— .02	—2.75
12	.40	.30	.25	.80	1.30	.60	—1.08	— .20	.15	—1.20	— .12	—2.65
13	.50	.30	.20	.70	.95	.50	— .60	— .35	.15	—1.40	— .17	—2.75
14	.55	.30	.20	.50	.83	.48	— .25	— .60	.20	—1.47	— .27	—2.90
15	.50	.30	.20	.55	.85	2.00	— .20	— .40	.50	—1.55	— .10	—3.00
16	.40	.33	.20	.60	1.70	1.85	.00	.....	.65	—1.35	— .07	—3.07
17	.40	.35	.45	.60	1.43	1.93	.15	.....	.60	.00	— .10	—3.15
18	.50	.35	.63	.50	1.10	1.83	.20	— .40	.60	.30	— .10	—3.15
19	.40	.28	.60	.50	.93	1.08	.20	+1.15	.50	.60	— .12	—3.00
20	.40	.30	.60	.50	1.20	.80	.50	1.45	.40	.57	— .40	—3.00
21	.40	.30	.50	.40	1.53	.73	.40	1.30	.40	.55	— .60	—3.15
22	.40	.30	.45	.30	.98	.58	.35	.85	.35	.50	— .65	—2.90
23	.40	.30	.40	.30	1.05	.45	.30	.80	.30	.57	— .70	—3.00
24	.40	.25	.40	.30	.70	.40	.25	.78	.28	.55	— .70	—2.90
25	.40	.25	.35	.30	.55	.38	.20	.65	.18	.50	— .70	—2.90
26	.40	.23	.40	.30	.50	.40	.60	.50	.15	.15	—1.37	—2.80
27	.40	.23	.30	.30	.48	.35	.40	.48	.15	.80	—1.55	—2.70
28	.40	.23	.85	.40	.40	.28	.50	.35	.10	.85	—1.60	—2.70
29	.40	.....	2.40	.35	.45	.28	.45	.40	.05	.65	—1.80	—2.70
30	.30	.....	2.80	.30	.40	.28	.38	.33	.03	.55	—2.00	—2.70
31	.30	.....	1.70	.....	.40	.....	.30	.30	.....	.55	.....	—2.00

y gage height, in feet, on crest of dam of Colorado River, at Austin, Texas, for 1898.

ay.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	—2.30	—1.60	0.20	—1.10	0.2	0.20	1.70	0.20	0.50	0.30	—3.90	—5.30
2	—2.30	—1.60	.20	—1.10	.30	.10	1.00	.20	.40	.30	—4.10	.....
3	—2.30	—1.60	.10	—1.30	.30	.10	.80	.20	.30	.20	—4.40	.....
4	—2.20	—1.50	.10	—1.20	.40	.10	.70	.10	.30	.10	—4.60	.....
5	—2.50	—1.50	.10	—1.30	.40	.10	1.10	.10	.30	.10	—4.80	.....
6	—2.50	—1.50	.05	—1.50	.30	.50	.70	.10	.20	.05	—5.00	.....
7	—2.50	—1.50	.05	—1.50	1.20	.00	.60	—.05	.20	.30	—5.20	—6.30
8	—2.50	—1.50	.00	—1.70	1.50	.00	.50	—.15	.10	.30	—5.50	—6.60
9	—2.50	—1.30	.00	—1.80	1.20	1.50	.50	—.10	.10	.20	—5.70	—6.80
10	—2.50	—1.10	.00	—2.00	.80	.90	.30	—.20	.10	.10	—5.90	—7.30
11	—2.40	— .50	.00	—2.00	.60	1.00	.40	—.30	.00	— .10	—5.90	—7.70
12	—2.40	— .20	.00	—1.90	.50	1.70	.40	—.30	— .10	.00	—5.70	—7.50
13	—2.40	.03	.00	+ .80	2.10	1.70	.30	.00	— .30	— .20	—4.70	—7.60
14	—2.40	.20	.00	1.80	2.20	2.30	.40	.70	— .40	— .30	—4.20	—7.40
15	—2.50	.20	.00	1.10	1.20	3.70	.40	.80	— .70	— .50	—3.80	—7.40
16	—2.50	.20	.00	.90	.90	4.20	.30	.70	— .80	— .60	—3.90	—7.40
17	—2.40	.50	.00	.70	.70	3.60	.30	.70	—1.00	— .50	—4.00	—8.00
18	—2.50	.40	.00	.80	.50	2.60	.30	.50	—1.20	— .90	—3.60	—7.30
19	—2.40	.40	.00	1.50	.50	3.90	.10	.50	—1.50	—1.00	—3.50	—7.10
20	—2.30	.40	.00	1.60	.40	4.00	.20	.05	—1.60	—1.30	—3.00	—6.90
21	—2.30	.30	.00	1.10	.40	3.40	.20	.00	—1.90	—1.80	—4.00	—6.60
22	—2.20	.20	.00	.90	.30	1.70	.40	—.10	—2.10	—1.50	—4.20	—6.50
23	—2.20	.30	— .10	.70	.30	1.40	.30	—.30	—2.50	—1.70	—4.30	—6.50
24	—2.10	.20	— .20	.50	.30	1.10	.30	—.40	+2.00	—2.00	—4.60	—6.30
25	—2.00	.20	— .30	.50	.30	.90	.30	—.50	1.70	—2.20	—4.40	—6.10
26	—1.90	.20	— .50	.40	.40	.70	.30	—.70	.90	—2.50	—4.60	—6.00
27	—1.90	.20	— .70	.30	.40	.70	.30	—.70	.70	—2.60	—4.70	—5.80
28	—1.80	.20	— .70	.30	.40	.70	.30	—.60	.50	—2.80	—4.80	—5.80
29	—1.80	.....	— .90	.30	.40	.70	.20	+.70	.40	—3.00	—4.80	—5.70
30	—1.70	.....	— .90	.20	.30	.80	.10	1.40	.30	—3.50	—4.90	—6.10
31	—1.70	.....	—1.00	.....	.20	.....	.20	1.30	.....	—3.60	.....	—5.80

Daily gage height, in feet, of Colorado River above Congress Avenue Brid Austin, Texas, for 1898.

Day.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	D
1	.....	2.10	1.95	2.25	2.00	4.10	1.95	2.55	2.35	1.95	1
2	.....	2.20	1.95	2.40	2.00	3.70	2.10	2.45	2.30	1.85	1
3	.....	2.15	1.95	2.40	2.00	3.20	2.25	2.55	2.25	1.95	1
4	.....	2.00	2.00	2.65	2.05	3.05	2.10	2.35	2.10	1.95	1
5	.....	2.00	1.95	2.40	2.05	3.05	2.15	2.45	2.05	1.95	1
6	.....	1.95	2.00	2.45	1.95	2.90	2.10	2.40	2.05	1.95	1
7	.....	1.90	1.95	3.65	1.95	2.85	1.95	2.30	2.25	1.95	1
8	.....	1.90	1.95	4.85	2.45	2.70	1.95	2.20	2.40	1.95	2
9	.....	1.95	1.95	3.90	4.00	2.55	2.00	2.10	2.25	2.00	2
10	.....	1.90	2.00	3.20	3.65	2.50	2.05	2.05	2.05	1.95	2
11	.....	2.00	2.00	2.85	4.10	2.55	2.05	2.05	2.00	2.00	2
12	.....	1.95	2.05	2.55	4.30	2.40	2.10	2.05	2.05	1.95	1
13	.....	1.95	3.40	7.00	4.50	2.35	2.35	2.00	2.20	1.95	1
14	.....	1.90	5.05	5.75	6.30	2.70	2.65	1.95	1.90	1.95	2
15	2.00	1.95	3.75	4.00	9.55	2.55	2.55	1.95	1.95	2.00	2
16	2.45	2.00	3.35	3.50	10.70	2.45	2.40	1.95	1.95	1.85	1
17	2.75	1.95	3.00	3.15	8.80	2.20	2.30	1.90	2.00	1.85	1
18	2.55	2.00	3.30	2.90	7.40	2.10	2.20	2.00	2.05	1.85	1
19	2.50	1.95	3.25	2.70	10.20	2.15	2.15	2.00	2.05	1.85	1
20	2.45	1.95	4.75	2.50	9.60	2.05	2.00	2.00	2.05	1.80	1
21	2.35	1.95	4.60	2.40	6.10	2.35	1.95	2.00	2.15	1.85	1
22	2.30	2.00	3.80	2.45	5.00	2.60	1.95	2.05	2.00	1.90	1
23	2.30	1.95	3.20	2.25	4.10	2.55	2.00	5.25	2.05	1.85	1
24	2.20	1.95	2.90	2.15	3.75	2.35	2.05	4.40	2.00	1.95	1
25	2.20	2.00	2.50	2.15	3.40	2.30	2.05	4.15	1.85	1.95	1
26	2.20	2.00	2.45	2.20	3.15	2.20	2.05	3.60	1.85	1.85	1
27	2.10	1.90	2.35	2.30	3.05	2.10	2.15	3.10	1.95	1.85	1
28	2.05	2.10	2.35	2.20	3.15	2.15	2.70	2.95	2.00	1.90	2
29	.....	2.00	2.30	2.15	3.30	2.00	2.90	2.60	1.50	1.90	1
30	.....	2.00	2.30	2.05	3.40	1.95	3.60	2.45	2.20	1.85	1
31	.....	1.95	.....	2.00	.....	1.95	2.95	.....	1.95	.....	1

Daily gage height, in feet, of Guadalupe River at New Braunfels, Texas, for

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	D
1	.....	2.00	2.10	2.00	2.25	2.00	2.20	2.00	2.00	2
2	.....	2.00	2.10	2.00	2.40	2.00	2.15	2.00	2.00	2
3	.....	2.00	2.10	2.00	2.30	2.00	2.10	2.00	2.00	2
4	.....	2.00	2.10	2.00	2.10	2.00	2.05	2.00	2.00	2
5	.....	2.00	2.10	2.00	2.10	2.00	2.00	2.00	2.00	2
6	.....	2.00	2.10	2.25	2.00	2.00	2.00	2.00	2.00	2
7	.....	2.00	2.10	2.10	2.00	2.00	2.00	2.00	2.00	2
8	.....	2.00	2.10	2.10	2.00	2.00	2.00	2.00	2.00	2
9	.....	2.00	2.10	2.35	2.00	2.00	2.00	2.00	2.00	2
10	.....	2.00	2.10	2.30	2.00	2.00	2.00	2.00	2.00	2
11	.....	2.00	2.10	2.40	2.00	2.00	2.00	2.00	2.00	2
12	.....	2.10	2.10	3.10	2.00	2.00	2.00	2.00	2.00	2
13	2.00	2.05	2.10	3.60	2.00	2.00	2.00	2.00	2.00	2
14	2.00	2.00	2.10	3.50	2.00	2.00	2.00	2.00	2.00	2
15	2.00	2.08	2.10	2.90	2.00	2.00	2.00	2.00	2.00	2
16	2.00	2.13	2.10	2.65	2.00	2.00	2.00	2.00	2.00	2
17	2.00	2.30	2.10	2.55	2.00	2.00	2.00	2.00	2.00	2
18	2.00	2.30	2.10	2.45	2.00	2.00	2.10	2.00	2.00	2
19	2.00	2.20	2.10	2.40	2.00	2.00	2.00	2.00	2.00	2
20	2.00	2.20	2.10	2.50	2.00	2.05	2.00	2.00	2.00	1
21	2.00	2.20	2.10	2.40	2.00	2.00	2.00	2.00	2.00	1
22	2.00	2.20	2.25	2.35	2.00	2.00	2.00	2.00	2.00	1
23	2.00	2.20	2.10	2.30	2.00	2.00	2.00	2.00	2.00	1
24	2.00	2.20	2.10	2.25	2.00	2.00	2.00	2.00	2.00	1
25	2.00	2.20	2.10	2.10	2.00	2.00	2.00	2.00	2.00	1
26	2.00	2.15	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1
27	2.00	2.10	2.00	2.00	2.00	2.05	2.00	2.00	2.00	1
28	2.00	2.10	2.00	2.05	2.00	2.00	2.00	2.00	2.00	1
29	2.00	2.10	2.00	2.15	2.00	2.00	2.00	2.00	2.00	1
30	2.00	2.10	2.00	2.00	2.00	2.40	2.00	2.00	2.00	1
31	2.00	.....	2.00	.....	2.00	2.25	.....	2.00	.....	1

Daily gage height, in feet, of water in flume of Margueretta Canal, over Pecos River, for 1898.

Day.	Jan.	Mar.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.50	1.50	1.50	2.30	1.80	1.70	1.95	2.20
2	1.50	1.50	1.70	2.30	1.80	1.80	1.95	2.20
3	1.50	1.50	1.70	2.30	1.80	1.70	1.95	2.20
4	1.50	1.50	1.70	2.30	1.80	1.70	1.95	2.13
5	1.50	1.50	1.80	2.30	1.80	1.70	1.95	2.10
6	1.50	1.50	1.50	2.30	1.80	1.70	1.95	2.10
7	1.50	1.50	1.80	2.30	1.80	1.75	1.95	2.10
8	1.50	1.50	1.70	2.30	1.80	1.75	2.00	2.10
9	1.50	1.50	1.70	2.20	1.70	1.70	2.00	2.15
10	1.50	1.50	1.70	2.00	1.80	1.70	2.00	2.20
11	1.50	1.50	1.50	2.00	2.10	1.75	2.00	2.10
12	1.50	1.50	1.50	2.00	2.20	1.80	2.00	2.15
13	1.50	1.50	1.70	2.00	2.20	1.80	2.10	2.20
14	1.50	1.50	1.80	2.00	2.20	1.80	2.10	2.20
15	1.50	1.50	1.90	2.00	2.00	1.80	2.15	2.20
16	1.50	1.50	1.80	2.00	2.00	1.80	2.20	2.18
17	1.50	1.50	1.70	2.00	1.80	1.80	2.20	2.15
18	1.50	1.50	1.80	1.90	1.80	1.85	2.20	2.15
19	1.50	1.50	1.80	1.90	1.80	1.85	2.20	2.18
20	1.50	1.50	1.80	1.90	1.80	1.85	2.20	2.15
21	1.50	1.50	1.90	1.90	1.90	1.85	2.15	2.10
22	1.50	1.50	2.10	1.80	1.90	1.90	2.10	2.10
23	1.50	1.50	2.20	1.80	1.60	1.90	2.10	2.10
24	1.50	1.50	2.20	1.80	1.70	1.90	2.10	2.10
25	1.50	1.50	2.10	1.50	1.70	1.90	2.20	2.15
26	1.50	1.50	2.10	1.80	1.70	1.90	2.23	2.20
27	1.50	1.50	2.20	1.70	1.70	1.90	2.20	2.15
28	1.50	1.50	2.30	1.90	1.70	1.90	2.20	2.05
29	1.50	1.50	2.30	1.80	1.70	1.90	2.20	1.95
30	1.50	1.50	2.30	1.90	1.70	1.90	2.20	1.80
31	1.50	1.50	2.30	1.80	.....	1.90	.....	1.80

Daily gage height, in feet, of Pecos River, under flume 6 miles above Pecos, Texas, for 1898.

Day.	Jan.	Mar.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.10	1.00	1.40	4.80	2.40	1.80	1.70	1.80
2	1.00	1.00	1.60	4.70	2.30	1.80	1.70	1.70
3	1.00	1.00	1.50	4.70	2.00	1.80	1.70	1.70
4	1.00	1.00	2.80	4.50	2.00	1.80	1.70	1.65
5	1.20	1.00	5.80	4.50	2.00	1.80	1.70	1.60
6	2.00	1.00	6.00	4.20	2.00	1.80	1.70	1.60
7	2.70	1.00	6.50	4.20	2.50	1.80	1.65	1.60
8	3.00	1.00	8.90	6.30	2.20	1.75	1.70	1.65
9	2.80	1.00	9.90	8.80	2.00	1.80	1.70	1.65
10	2.80	1.00	10.70	6.50	2.00	1.80	1.70	1.65
11	2.80	.80	8.00	5.70	2.40	1.90	1.70	1.50
12	2.70	.70	7.00	5.30	2.30	1.90	1.70	1.60
13	2.70	.80	6.20	5.00	2.40	1.80	1.75	3.10
14	2.30	1.00	8.00	4.50	2.30	1.80	1.75	3.20
15	1.80	1.00	11.20	4.50	2.10	1.75	1.75	3.10
16	1.50	1.00	10.80	4.70	2.00	1.70	1.75	3.05
17	1.50	.90	9.00	4.50	2.00	1.70	1.80	3.00
18	1.70	.90	7.00	4.00	2.00	1.70	1.80	3.10
19	1.80	.80	6.00	3.00	2.00	1.65	1.80	3.10
20	2.00	.80	5.50	2.00	2.00	1.65	1.80	3.15
21	2.30	.70	7.00	1.50	2.00	1.70	1.80	3.80
22	2.20	.70	8.20	2.50	2.00	1.70	1.80	3.80
23	2.10	.70	8.00	2.50	2.00	1.70	1.75	3.70
24	2.00	.60	7.50	2.30	1.90	1.70	1.80	3.60
25	2.00	.60	6.80	2.40	1.90	1.70	1.80	4.30
26	1.90	.60	5.80	2.70	1.90	1.70	1.85	4.60
27	1.90	.60	5.00	2.00	1.90	1.70	1.85	4.60
28	1.90	.60	5.00	2.30	1.90	1.70	1.85	4.05
29	1.90	.60	4.90	2.00	1.90	1.70	1.86	3.75
30	1.90	.60	4.80	2.00	1.90	1.70	1.85	3.10
31	1.90	.60	4.80	2.00	.....	1.70	.....	2.85

Daily gage height, in feet, of Rio Grande at San Marcial, New Mexico, for

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Nov.
1	7.70	7.80	7.80	7.40	9.85	8.20	8.50	6.65	4.40	.....
2	7.70	8.00	7.80	7.40	9.65	8.15	8.60	6.55	4.30	.....
3	7.60	7.90	7.90	7.40	9.45	8.50	8.30	6.40	4.00	.....
4	7.60	7.80	7.80	7.40	9.10	8.40	8.55	6.30	4.00	.....
5	7.60	7.70	7.80	7.40	8.90	8.40	8.35	6.20	3.80	3.35
6	7.60	7.70	7.80	7.40	8.80	8.25	8.40	6.00	3.80	3.80
7	7.70	7.70	7.80	7.60	8.70	8.65	8.35	6.00	3.80	4.00
8	7.70	7.70	7.70	7.60	8.60	8.50	7.95	6.60	3.80	4.20
9	7.70	7.80	7.70	7.60	8.60	8.30	7.75	6.00	3.80	4.55
10	7.70	7.80	7.70	7.70	8.60	8.80	8.25	7.50	5.40	4.85
11	7.70	7.90	7.80	8.10	8.70	8.60	7.65	7.75	7.55	5.05
12	7.70	7.90	7.80	8.25	8.60	8.75	7.60	6.90	5.60	5.40
13	7.70	7.90	7.80	8.35	8.55	8.85	7.40	6.35	4.90	5.70
14	7.70	7.80	7.80	8.60	8.55	8.70	9.30	6.00	4.65	5.80
15	7.70	7.80	7.90	8.60	8.65	8.65	8.65	5.85	4.30	5.90
16	7.70	7.70	7.90	8.80	8.80	8.60	10.40	5.70	4.00	6.00
17	7.70	7.70	7.80	9.00	8.75	8.45	10.75	5.50	3.80	6.20
18	7.70	7.60	7.70	9.30	8.60	8.20	10.25	5.50	3.80	6.40
19	7.70	7.60	7.70	9.60	8.50	8.40	8.35	6.00	3.60	6.20
20	7.70	7.70	7.70	9.90	8.50	8.30	7.95	6.30	3.60	6.20
21	7.70	7.70	7.70	9.80	8.40	8.20	7.80	6.10	3.60	6.30
22	7.70	7.60	7.70	9.50	8.20	8.60	7.70	5.75	3.60	6.40
23	7.70	7.80	7.70	9.20	8.00	8.50	7.65	5.50	3.60	6.50
24	7.60	7.90	7.60	9.70	8.00	8.60	7.60	5.25	3.60	6.30
25	7.50	7.80	7.60	9.70	7.90	8.50	7.50	5.00	.....	6.60
26	7.35	7.80	7.50	9.75	7.80	8.75	7.40	4.90	.....	6.50
27	6.80	7.80	7.50	9.65	7.70	8.75	7.30	4.80	.....	6.50
28	7.00	7.80	7.50	9.70	7.70	8.65	7.20	5.15	.....	6.55
29	7.45	.....	7.50	9.75	7.70	8.55	7.10	5.10	.....	6.50
30	7.70	.....	7.50	10.00	7.80	8.40	7.00	4.70	.....	6.60
31	7.80	.....	7.40	.....	7.90	.....	6.80	4.50	.....	.....

Sept. 5-9, water standing in pools. Sept. 10-16, water backed up. Sept. 19-24, standing
Sept. 25-Nov. 4, dry.

Daily gage height, in feet, of Rio Grande at El Paso, Texas, for 1898

Day.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	6.85	7.45	6.30	10.90	7.50	9.50	7.50	5.55	4.20	4.00
2	7.05	7.35	6.30	11.00	7.50	9.50	7.50	5.40	4.20	4.00
3	7.30	7.45	6.10	11.30	7.55	9.40	7.30	5.40	4.20	4.00
4	8.05	7.35	5.95	11.30	7.95	9.45	7.05	5.35	4.20	4.00
5	8.30	7.55	5.75	10.95	8.20	9.30	7.35	5.30	4.20	4.00
6	8.05	7.25	5.55	10.70	8.70	10.60	7.15	5.20	4.20	4.00
7	7.90	7.30	5.40	10.20	9.40	10.60	7.10	5.25	4.20	4.00
8	8.10	7.20	5.40	9.80	9.25	9.65	7.05	5.25	4.20	4.00
9	8.10	7.30	5.30	9.55	9.25	9.60	8.05	5.20	4.20	4.00
10	7.80	7.30	5.30	9.40	9.90	9.75	7.50	5.15	4.20	4.00
11	7.55	7.50	5.30	9.40	10.10	9.55	7.50	5.20	4.20	4.00
12	7.50	7.60	5.20	9.35	10.05	10.00	7.10	4.95	4.20	4.00
13	7.80	7.50	5.10	9.10	9.90	9.60	8.45	4.75	4.20	4.00
14	7.70	7.45	5.10	8.95	9.80	9.30	7.95	4.55	4.20	4.00
15	7.65	7.50	5.20	9.00	9.80	9.15	7.55	5.85	4.20	4.00
16	7.70	7.40	6.75	9.00	9.50	9.05	7.25	5.65	4.20	4.00
17	7.75	7.55	8.55	9.05	9.35	10.60	7.00	5.45	4.20	4.00
18	7.55	7.80	8.75	9.10	9.25	11.70	6.65	5.35	4.20	4.00
19	7.40	7.70	9.15	9.10	9.15	13.55	6.55	5.25	4.20	4.00
20	7.35	7.45	9.60	9.10	8.85	13.65	6.35	5.10	4.10	4.00
21	7.30	7.25	9.95	9.05	8.70	13.00	6.15	5.05	4.10	4.00
22	7.20	7.10	10.40	8.90	8.70	10.95	6.00	4.90	4.10	4.00
23	7.10	7.00	10.50	8.75	8.80	9.75	6.00	4.80	4.00	4.00
24	7.10	6.90	10.80	8.65	8.95	9.10	6.00	4.70	4.00	4.00
25	7.15	6.90	10.70	8.45	9.65	9.05	5.90	4.60	4.00	4.00
26	7.70	6.75	10.60	8.30	9.80	8.90	5.85	4.55	4.00	4.00
27	7.65	6.60	10.80	8.25	9.60	8.40	5.70	4.50	4.00	4.10
28	7.55	6.50	10.70	8.05	9.60	8.30	5.75	4.45	4.00	4.10
29	.....	6.40	10.70	7.80	9.65	7.95	6.15	4.40	4.00	4.10
30	.....	6.30	10.75	7.55	9.65	7.90	5.95	4.30	4.00	4.10
31	.....	6.30	.....	7.50	.....	7.80	5.75	.....	4.00	.....

List of discharge measurements.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
				Feet.	*Sec.-feet.*
1898.					
Dec. 30	Trinity River	Dallas, Tex	T. U. Taylor	55.80	48
Sept. 14	Brazos River	Waco, Tex	do	2.70	243
Dec. 26	do	do	do	2.50	142
Dec. 31	do	do	do	2.50	142
Feb. 22	do	Lewis, Tex	do	7.00	1,612
May 20	do	do	do	7.80	2,017
1897.					
Dec. 21	Colorado River	Austin, Tex	do	1.80	290
Dec. 22	do	do	do	1.95	355
Dec. 23	do	do	do	2.00	392
Dec. 24	do	do	do	2.05	408
Dec. 25	do	do	do	1.70	275
Dec. 28	do	do	do	1.70	278
1898.					
Jan. 5	do	do	do		a 226
Jan. 6	do	do	do		a 230
Jan. 7	do	do	do		a 233
Jan. 13	do	do	do		a 234
Jan. 22	do	do	do	1.80	297
Feb. 14	do	do	do	2.00	386
Do.	do	do	do	2.00	382
Feb. 17	do	do	do	2.71	1,080
Feb. 18	do	do	do	2.71	1,087
Feb. 19	do	do	do	2.52	876
Mar. 8	do	do	do	1.90	311
Apr. 28	do	do	do	2.38	581
Sept. 15	do	do	do	1.96	
Dec. 16	do	do	do	1.95	343
Dec. 21	do	do	do		a 298
Dec. 22	do	do	do		a 296
Mar. 12	Guadalupe River	New Braunfels, Tex.	do	2.00	350
Dec. 20	do	do	do	1.90	44
Apr. 14	Rio Grande	Del Norte, Colo	P. E. Harroun	3.27	1,966
May 18	do	do	do	3.23	1,802
June 23	do	do	do	5.25	5,181
Aug. 25	do	do	do	1.86	521
Oct. 28	do	do	do	1.48	244
Sept. 18	do	Embudo, N. Mex	do	7.70	271
Oct. 6	do	do	do	7.50	265
Oct. 28	do	do	do	7.60	284
May 19	do	Rio Grande, N. Mex.	do	7.00	2,671
Sept. 17	do	do	do	4.70	269
Oct. 7	do	do	do	4.60	258
Oct. 29	do	do	do	5.00	368
May 16	do	San Marcial, N. Mex.	do	8.80	2,943
Sept. 15	do	do	do	4.30	46

a Gaging made in tailrace at dam.

List of miscellaneous discharge measurements.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
1897.				*Feet.*	*Sec.-feet.*
Dec. 30	San Antonio River.	San Antonio, Tex.	T. U. Taylor		11
1898.					
Jan. 1	Brazos River	Harlans Ford, Tex.	do		132
Jan. 8	Colorado River	Sulphur Hollow, Tex.	do		227
Jan. 12	Comal River	New Braunfels, Tex.	do	1.40	288
Jan. 14	San Felipe River	Del Rio, Tex	do		43
Do.	Madre Ditch	do	do		25
Jan. 15	Devils River	Southern Pacific railroad bridge, Tex.	do		362
Mar. 17	San Antonio River.	Hot Wells, Tex	do		9
Mar. 18	Comal River	New Braunfels, Tex.	do	1.40	312
Mar. 19	San Marcos River	San Marcos, Tex	do		51
Mar. 26	Barton Spring	Austin, Tex	do		29
May 3	do	do	do		30
Do.	do	do	do		31
Sept. 5	Pecos River	Flume 6 miles above Pecos, Tex.	do	2.00	80
Do.	Margueretta Flume	6 miles above Pecos, Tex.	do	1.80	114
Sept. 6	Arroya Flume	Below Lake Avalon, Tex.	do		321
Sept. 7	Pecos River	Eddy, N. Mex	do		157
Sept. 8	Delaware River	Crossing of Pecos Valley Railroad.	do		4
Do.	Pecos River	Redbluff, N. Mex	do		227
Sept. 12	Brazos River	Brazos, Tex	do	3.25	80
Sept. 13	Trinity River	Fort Worth, Tex	do		11
Sept. 16	San Marcos River	Westfield, Tex	do		86
Dec. 23	Barton Spring	Austin, Tex	do		19
Dec. 24	do	do	do		19

Rating tables.

Del Norte.		Embudo.		Rio Grande.		San Marcial.	
Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*
1.4	194	7.5	265	4.3	230	5.0	5
1.5	260	7.6	285	4.4	240	5.2	21
1.6	328	7.7	310	4.5	250	5.4	37
1.7	398	7.8	345	4.6	260	5.6	53
1.8	468	7.9	385	4.7	270	5.8	69
1.9	540	8.0	425	4.8	290	6.0	85
2.0	614	8.2	515	4.9	320	6.2	101
2.1	692	8.4	605	5.0	360	6.4	120
2.2	772	8.6	725	5.2	450	6.6	170
2.3	856	8.8	875	5.4	560	6.8	270
2.4	942	9.0	1,025	5.6	710	7.0	400
2.5	1,032	9.2	1,175	5.8	880	7.2	580
2.6	1,128	9.4	1,360	6.0	1,090	7.4	850
2.7	1,228	9.6	1,570	6.2	1,330	7.6	1,200
2.8	1,333	9.8	1,790	6.4	1,590	7.8	1,650
2.9	1,442	10.0	2,010	6.6	1,910	8.0	2,150
3.0	1,556	10.2	2,260	6.8	2,250	8.2	2,800
3.2	1,811	10.4	2,540	7.0	2,670	8.4	3,600
3.4	2,120	10.6	2,820	7.2	3,110	8.6	4,450
3.6	2,440	10.8	3,105	7.4	3,550	8.8	5,350
3.8	2,760	11.0	3,395	7.6	3,990	9.0	6,250
4.0	3,080	11.2	3,685	7.8	4,450	9.2	7,150
4.2	3,406	11.4	3,975	8.0	4,910	9.4	8,050
4.4	3,737	11.6	4,265	8.2	5,380	9.6	8,925
4.6	4,076	11.8	4,555	8.4	5,860	9.8	9,850
4.8	4,416	12.0	4,845	8.6	6,340	10.0	10,750
5.0	4,756			8.8	6,820	10.2	11,650
5.2	5,096			9.0	7,300	10.4	12,550
5.4	5,436			9.2	7,780		
				9.4	8,260		

COLORADO RIVER DRAINAGE.

DESCRIPTION OF RIVER STATIONS.

station on Black Fork.—Described on page 134 of Paper
ıults for 1897 given on pages 391–393 of the Nineteenth
ıport, Part IV.

er station on Green River.—Described on page 135 of
16; results for 1897 shown on pages 394–396 of the Nine-
ıual Report, Part IV.

ıtion on Green River.—Described on page 136 of Paper No.
for 1897 given on pages 396–398 of the Nineteenth Annual
ırt IV.

unction station on Grand River.—Described on page 137
o. 16; results for 1897 given on pages 399–401 of the Nine-
ıual Report, Part IV.

wford station on Uncompahgre River.—Described on page
er No. 16; results for 1897 given on pages 402–404 of the
ı Annual Report, Part IV.

unction station on Gunnison River.—Described on page
er No. 16; results for 1897 given on pages 404–406 of the
ı Annual Report, Part IV.

: station on San Miguel River.—Described on page 142
o. 16; results for 1897 given on pages 406–407 of the Nine-
ıual Report, Part IV.

station on Mancos River.—This station is located at about
of the town of Mancos, Colorado, 100 feet below a wagon
ıss the river, and was established April 9, 1898. The gage
a vertical 2 by 4 inch by 12 foot timber, marked in tenths,
ired and spiked to a cottonwood tree on left bank of
asurements are usually made by wading, but the wagon
be used at high water, the initial point being on the left
banks are not liable to overflow. The channel is in
is not liable to much change. The channel is straight for
ove and 300 feet below. The location of the station is such
scharge is practically the amount lost to irrigation, most of
ı being taken out above. The observer is Mrs. K. D.
o lives about 200 feet from the gage.

ıtation on Dolores River.—Described on page 143 of Paper
sults for 1897 given on pages 407–409 of the Nineteenth
port, Part IV.

station on San Juan River.—Described on page 144 of
16; results for 1897 given on pages 409–410 of the Nineteenth
port, Part IV. The footbridge was washed out in August.
er is J. D. Lister.

ıtation on Piedra River.—Described on page 145 of Paper
ıults for 1897 given on pages 411–413 of the Nineteenth
port, Part IV. The observer is J. D. Lister.

Durango station on Animas River.—Described on page 146 of Paper No. 16; results for 1897 given on pages 414–415 of the Nineteenth Annual Report, Part IV.

Queen Creek station on Queen Creek.—Described on page 417 of Nineteenth Annual Report, Part IV. Observations were not begun until July 1, 1898. It is reported that there was water in the creek earlier in the year, probably in January or February, but the quantity was not notably large. From that time the bed was dry until August 8, and again dry from September 2 to December 17; on December 18 a discharge of 20 second-feet was reported, and the creek was again dry from December 19 to 31. From July 1 to September 10 the observer was John Green. His record is given below showing date, height of water, and area of cross section computed by Mr. Cyrus C. Babb, by using the cross section made by Mr. Albert T. Colton on July 15, 1898.

Height of water and area of cross section of Queen Creek.

Date.	Gage height.	Area.
	Feet.	*Sq. feet.*
August 8, night	4.5	121
August 18, afternoon	24.2	100
August 22, afternoon	5.2	220
August 23, afternoon	4.4	113
August 27, afternoon	5.4	200
August 29, 7.30 p. m.	7.0	605
August 30, 5 a. m.	(*a*)	(*a*)
August 31, 2 p. m.	9.0	691
September 1, 7 a. m.	(*b*)	(*b*)
September 1, 2 p. m.	4.0	111

a No flow. *b* Rising.

The flood of August 31 modified the channel of the creek to a considerable extent. The area of cross section since that time has been computed from measurements made December 27, 1898. On November 16 Mr. Babb extended the rod, lowering the zero by 3 feet and changing the records made before that time to accord with the new datum. On the same day a sloping rod referred to the same datum was placed 431 feet upstream from the main gage. The creek was dry from September 10 until December 16. The observer, W. E. Holman, reported that water appeared at Hewitt's ranch on the morning of December 17, the quantity being about 10 second-feet and somewhat more at night. This water reached a tank 400 feet above the upper rod or approximately 2 miles below Hewitt's at 3 p. m. December 17; on December 18, at 9 a. m., and again at 4 p. m. the lower gage read 2.0 feet and the upper gage 6.0 feet; the creek was then 25 feet wide and the discharge about 20 second-feet. On December 18 the creek at the gages was again dry. For several days thereafter there was a slight flow at Hewitt's, but this did not reach the gages, being absorbed in the sandy channel. From the facts available Mr. Babb has roughly estimated that the discharge for the creek for the year 1898 was 5,000

acre-feet, not taking into account the quantity which may have flowed during the early part of the year.

Buttes station on the Gila River.—Described on page 147 of Paper No. 16; results for 1897 given on pages 415–417 of the Nineteenth Annual Report, Part IV. The bench mark described in the Annual Report for 1897, consisting of an X chiseled in the face of the rock, has been destroyed and a new one established. This is on a ledge of rock 69.4 feet east of south cable anchor and 4.4 feet above ground. Its elevation is 1,608.45 feet above sea level. The zero of the gage is 1,583 feet or 25.45 feet below this bench mark. Occasional measurements, as shown on page 142, have been made, but systematic observations could not be had until November 25, 1898. Since that date computations of daily discharge have been made.

McDowell station on Salt River.—Described on page 148 of Paper No. 16; results for 1897 given on pages 418–420 of the Nineteenth Annual Report, Part IV.

McDowell station on Verde River.—Described on page 150 of Paper No. 16; results for 1897 given on pages 420–423 of the Nineteenth Annual Report, Part IV. No constant relation between gage height and discharge being discoverable, no rating table was constructed, the daily mean discharges being obtained by approximation.

Yuma station on Colorado River.—Described on page 151 of Paper No. 16.

TABLES OF DAILY GAGE HEIGHT.

Daily gage height, in feet, of Black Fork at Granger, Wyoming, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Oct.	Nov.	Dec.
1	1.10			2.35	2.80	2.80	1.65	0.20		0.20	
2				2.50	2.65	2.85	1.55	.15	0.00	.20	
3				3.10	2.50	3.00	1.40	.10	.00	.10	
4				2.80	2.25	2.85	1.30	.10	.00	.10	
5		1.00	2.60	2.10	2.20	2.75	1.25	.10	.00	.10	
6				1.90	2.15	2.65	1.20	.10	.05	.00	0.50
7	1.10			2.00	2.20	2.60	1.10	.10	.10	.00	
8				2.00	2.25	2.35	1.10	.10	.10	.00	
9				2.50	2.35	2.40	1.10	.10	.10	.00	
10				2.95	2.20	2.35	1.10	.10	.10	.00	
11				2.70	2.25	2.40	1.10	.10	.10	.00	
12		1.00	2.00	2.80	2.45	2.45	1.10	.10	.20	.20	
13				2.65	2.65	2.50	1.10	.00	.20	.00	
14				2.50	3.00	2.80	1.10	.00	.20	.00	
15	1.10			2.50	3.05	3.05	1.00	.00	.20	.00	.50
16				2.70	2.95	2.90	.90	.00	.20	.00	
17				2.80	2.95	2.95	.80	.00	.20	.00	
18				2.95	3.40	3.35	.70	.25	.40	.00	
19		2.60	1.90	3.00	3.05	3.25	.60	.50	.30	.20	
20				2.70	3.00	2.95	.50	.40	.30	.00	
21				2.60	2.65	2.90	.50	.30	.20	.00	
22	1.10			2.95	2.40	2.95	.50	.20	.20	.00	
23				2.90	2.25	2.75	.50	.10	.20	.00	.50
24				2.50	2.65	3.10	.45	.10	.20	.00	
25				2.35	2.90	3.10	.40	.00	.20	.00	
26		1.90	1.60	2.35	3.00	2.60	.40	.00	.20	.50	
27				2.80	3.00	2.20	.40	.00	.20		
28				3.15	2.95	2.05	.30	.00	.20		
29	1.10			3.10	3.00	2.00	.30	.00	.20		
30				3.00	2.95	1.90	.20	.00	.20		
31			2.10		2.75		.20	(a)	.20		.50

a August 31 to October 2, water standing in pools.

Daily gage height, in feet, of Green River at Greenriver, Wyoming, for 1

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	I
1	1.20	2.60	3.65	4.00	2.00	1.45	0.78	0.80	...
2	1.25	2.58	3.48	3.85	1.95	1.40	.80	.....	...
3	1.35	3.53	3.28	3.68	1.93	1.43	.85	.80	...
4	1.47	2.50	3.30	3.50	1.83	1.45	.85	.....	...
5	1.53	2.45	3.40	3.43	1.75	1.40	.90	.80	...
6	1.43	2.40	3.33	3.38	1.75	1.38	.90	.80	...
7	1.27	2.33	3.23	3.33	1.78	1.33	.85	.80	...
8	1.45	2.28	3.13	3.23	1.78	1.25	.85	.80	...
9	1.45	2.13	3.03	3.13	1.75	1.23	.85	.80	...
10	1.55	2.23	2.95	3.10	1.70	1.18	.90	.70	1
11	1.60	2.28	3.00	3.10	1.65	1.15	.90	.75	...
12	2.10	2.35	3.08	3.13	1.62	1.10	.90	1.50	...
13	2.98	2.43	3.20	3.20	1.58	1.10	.90	1.40	...
14	3.13	2.68	3.50	3.25	1.55	1.05	.90	1.20	...
15	2.95	2.85	3.85	3.23	1.60	1.05	.90	1.00	1
16	2.83	2.93	4.05	3.15	1.65	1.03	.90	.90	1
17	3.00	2.95	4.23	3.10	1.65	1.00	.85	.60	...
18	3.23	2.95	4.33	3.05	1.60	1.00	.85	.80	...
19	3.08	3.03	4.45	2.98	1.55	.95	.85	.90	1
20	2.73	3.00	4.63	2.88	1.55	.95	.85	.90	...
21	2.55	2.98	4.68	2.65	1.55	.90	.85	.90	...
22	2.48	2.78	4.75	2.45	1.50	.90	.85	.85	...
23	2.35	2.60	4.83	2.33	1.48	.85	.80	.80	1
24	2.45	2.65	4.90	2.30	1.38	.83	.80	.80	...
25	2.35	2.85	4.98	2.30	1.33	.80	.80	.80	...
26	2.35	3.43	5.15	2.25	1.25	.80	.80	.85	1
27	2.38	3.50	5.23	2.23	1.20	.80	.80	.....	...
28	2.48	3.50	4.88	2.20	1.15	.80	.80	.....	...
29	2.60	3.58	4.53	2.15	1.13	.75	.80	.....	...
30	2.63	3.70	4.25	2.08	1.28	.75	.80	.....	...
31	.....	3.65	.....	2.03	1.45	.....	.80	.....	1

Daily gage height, in feet, of Green River at Blake, Utah, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	D
1	1.35	4.10	4.00	3.20	6.30	6.65	7.05	2.95	2.15	1.50	2.00	1
2	1.40	4.00	4.10	3.10	6.30	6.70	6.90	2.90	2.25	1.60	2.10	1
3	1.50	3.90	4.15	3.00	6.20	6.85	6.75	2.80	2.25	1.60	2.00	1
4	1.75	4.00	4.25	3.00	6.30	7.00	6.55	2.70	2.40	1.60	2.20	1
5	1.95	4.10	4.30	2.95	6.20	6.90	6.20	2.65	2.70	1.70	2.10	1
6	2.40	4.00	4.20	2.90	6.30	6.80	5.80	2.55	2.60	1.70	2.00	1
7	2.70	4.00	4.10	3.00	6.30	6.70	5.40	2.50	2.30	1.70	2.10	1
8	3.00	4.10	4.05	3.10	6.60	6.65	5.15	2.50	2.30	1.70	2.00	1
9	3.25	3.90	3.95	3.20	6.30	6.60	5.05	2.40	2.25	1.70	2.10	1
10	3.45	4.00	3.85	3.30	6.30	6.40	5.00	2.40	2.25	1.80	2.00	1
11	3.70	3.95	3.65	3.45	6.30	6.30	5.20	2.40	2.40	1.80	2.10	1
12	3.80	3.75	3.45	3.70	6.30	6.35	5.10	2.40	2.30	1.80	2.10	1
13	4.00	3.65	3.25	4.10	6.10	6.45	5.00	2.40	2.20	1.90	2.10	1
14	3.90	3.55	3.20	4.45	6.30	6.55	5.10	2.40	2.20	1.90	2.05	1
15	4.00	3.60	3.20	4.60	6.30	6.65	5.00	2.40	2.10	1.90	1.30	1
16	4.10	3.70	3.15	4.90	6.40	6.75	4.90	2.40	2.10	1.90	1.30	1
17	3.95	3.80	3.10	5.25	6.50	6.80	5.00	2.40	2.00	1.90	1.40	1
18	3.95	3.60	3.05	5.45	6.40	6.90	4.85	2.40	2.00	1.90	1.30	1
19	4.10	3.70	3.00	5.65	6.30	6.95	4.55	2.40	2.00	1.90	1.20	1
20	4.00	3.70	3.00	5.85	6.30	7.00	4.40	2.50	2.00	1.90	1.30	1
21	3.90	3.70	3.00	6.05	6.20	7.10	4.30	2.40	1.90	1.90	1.20	1
22	4.00	3.80	3.00	6.20	6.30	7.20	4.20	2.40	1.90	2.00	1.20	1
23	4.05	3.80	3.00	6.30	6.40	7.35	4.10	2.40	1.85	2.00	1.20	1
24	4.00	3.90	3.00	6.25	6.35	7.60	4.00	2.40	1.80	2.00	1.30	1
25	4.10	3.90	3.00	6.15	6.35	7.90	3.90	2.40	1.75	2.00	1.30	1
26	3.95	3.90	3.00	6.05	6.40	7.75	3.80	2.40	1.70	2.00	1.30	1
27	3.95	3.90	3.05	5.90	6.30	7.55	3.70	2.35	1.55	2.00	1.30	1
28	4.10	4.00	3.35	6.00	6.40	7.50	3.50	2.30	1.40	2.00	1.40	1
29	3.95	.....	3.50	6.10	6.40	7.40	3.25	2.30	1.40	2.00	1.50	1
30	4.00	.....	3.40	6.20	6.45	7.30	3.15	2.30	1.45	2.00	1.50	1
31	4.00	.....	3.30	.....	6.55	.....	3.05	2.20	.....	2.00	.....	1

[illegible] height, in feet, of Grand River, left channel, rod No. [illegible], at Grand Junction, Colorado, for [illegible].

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
4.00				4.05	7.70	4.45	1.40	1.30	1.10	1.10	1.00
			3.60	5.40	7.00	4.00	1.30	1.10	1.10	1.10	1.00
				5.45	9.30	4.25	1.30	1.10	1.10	1.10	1.10
				5.30	9.40	4.00	1.00	1.10	1.10	1.10	
4.40		3.90		5.30	9.35	3.75	1.00	1.10	1.10	1.10	
				5.30	7.35	3.60	1.00	1.10	1.10	1.10	
				5.20	7.40	3.50	1.00	1.10	1.10	1.10	1.10
4.70				5.20	7.30	3.40	1.00	1.25	1.10	1.10	
			4.10	5.20	7.45	3.40	1.00	1.20	1.10	1.10	
				5.10	7.40	3.40	1.01	1.20	1.10	1.10	1.10
				5.25	7.35	3.30	1.15	1.30	1.20	1.20	
4.10		3.80		5.05	7.05	3.30	1.10	1.30	1.20	1.30	
				5.05	7.25	3.45	1.10	1.30	1.20	1.20	1.10
				4.55	7.25	3.55	1.10	1.30	1.25	1.20	
4.20				4.65	7.45	3.60	1.10	1.20	1.20	1.20	
			4.00	4.35	4.15	3.35	1.20	1.20	1.20	1.20	
				4.30	4.00	3.25	1.20	1.20	1.10	1.20	1.10
				4.20	4.50	4.35	1.20	1.20	1.10	1.20	
4.10	4.50	3.70		4.20	4.40	4.00	1.20	1.25	1.10	1.20	
				4.20	4.65	4.45	1.20	1.20	1.15	1.20	
				4.05	4.35	4.45	1.20	1.20	1.10	1.10	1.20
4.10				3.90	4.20	4.00	1.20	1.20	1.10	1.00	
			5.10	3.85	4.15	4.20	1.20	1.20	1.10	1.00	
				4.20	4.25	4.25	1.20	1.20	1.10	1.10	1.20
			5.10	4.55	7.30	4.05	1.10	1.20	1.10	1.10	
4.00	3.80	3.80		7.05	7.45	4.10	1.00	1.20	1.10	1.10	
				7.20	7.40	4.10	1.10	1.20	1.10	1.10	1.20
				7.40	7.20	4.05	1.20	1.20	1.10	1.10	
				7.70	4.45	4.40	1.25	1.15	1.15	1.10	
			6.20	7.70	4.45	4.70	1.20	1.10	1.15	1.00	
				7.40		4.40	1.20		1.10		4.00

[illegible] height, in feet, of Grand River, right channel, rod [illegible], at Grand Junction, Colorado, for [illegible].

May.	June.	July.	Day.	May.	June.	July.	Day.	May.	June.	July.
	0.70	[illegible]	12		[illegible].95		23	[illegible]	[illegible]	
	.90	[illegible]	13		[illegible].75		24	[illegible]	[illegible]	
	1.30		14		[illegible].75		25	[illegible]	[illegible]	
	1.00		15		[illegible].95		26	[illegible]	[illegible]	
	1.35		16		1.25		27	[illegible]	[illegible]	
	.95		17		1.00		28	[illegible]	[illegible]	
	.90		18		1.00		29	[illegible]	[illegible]	
	.90		19		1.00		30	[illegible]	[illegible]	
	.85		20		1.05		31	[illegible]	[illegible]	
	.90		21		1.00					
	.70		22	[illegible]	[illegible].25					

Daily gage height, in feet, of Green River at Greenriver, Wyoming, for 18

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	De
1	1.20	2.60	3.65	4.00	2.00	1.45	0.78	0.80	....
2	1.25	2.58	3.48	3.85	1.95	1.40	.80	.....	....
3	1.35	3.53	3.28	3.68	1.93	1.43	.85	.80	....
4	1.47	2.50	3.30	3.50	1.83	1.45	.85	.....	....
5	1.53	2.45	3.40	3.43	1.75	1.40	.90	.80	....
6	1.43	2.40	3.33	3.38	1.75	1.38	.90	.80	....
7	1.27	2.33	3.23	3.33	1.78	1.33	.85	.80	....
8	1.45	2.28	3.13	3.23	1.78	1.25	.85	.80	....
9	1.45	2.13	3.03	3.13	1.75	1.23	.85	.80	....
10	1.55	2.23	2.95	3.10	1.70	1.18	.90	.70	1.
11	1.60	2.28	3.00	3.10	1.65	1.15	.90	.75	....
12	2.10	2.35	3.08	3.13	1.62	1.10	.90	1.50	....
13	2.98	2.43	3.20	3.20	1.58	1.10	.90	1.40	....
14	3.13	2.68	3.50	3.25	1.55	1.05	.90	1.20	....
15	2.95	2.85	3.85	3.23	1.60	1.05	.90	1.00	1.
16	2.83	2.93	4.05	3.15	1.65	1.03	.90	.90	1.
17	3.00	2.95	4.23	3.10	1.65	1.00	.85	.60	....
18	3.23	2.95	4.33	3.05	1.60	1.00	.85	.80	....
19	3.08	3.03	4.45	2.98	1.55	.95	.85	.90	1.
20	2.73	3.00	4.63	2.88	1.55	.95	.85	.90	....
21	2.55	2.98	4.68	2.65	1.55	.90	.85	.90	....
22	2.48	2.78	4.75	2.45	1.50	.90	.85	.85	....
23	2.35	2.60	4.83	2.33	1.48	.85	.80	.80	1.
24	2.45	2.65	4.90	2.30	1.38	.83	.80	.80	....
25	2.35	2.85	4.98	2.30	1.33	.80	.80	.80	....
26	2.35	3.43	5.15	2.25	1.25	.80	.80	.85	1.
27	2.38	3.50	5.23	2.23	1.20	.80	.80	.....	....
28	2.48	3.50	4.88	2.20	1.15	.80	.80	.....	....
29	2.60	3.58	4.53	2.15	1.13	.75	.80	.....	....
30	2.63	3.70	4.25	2.08	1.28	.75	.80	.....	....
31	.....	3.65	.....	2.03	1.45	.....	.80	.....	1.

Daily gage height, in feet, of Green River at Blake, Utah, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	De
1	1.35	4.10	4.00	3.20	6.30	6.65	7.05	2.95	2.15	1.50	2.00	1.
2	1.40	4.00	4.10	3.10	6.30	6.70	6.90	2.90	2.25	1.60	2.10	1.
3	1.50	3.90	4.15	3.00	6.20	6.85	6.75	2.80	2.25	1.60	2.00	1.
4	1.75	4.00	4.25	3.00	6.30	7.00	6.55	2.70	2.40	1.60	2.20	1.
5	1.95	4.10	4.30	2.95	6.20	6.90	6.20	2.65	2.70	1.70	2.10	1.
6	2.40	4.00	4.20	2.90	6.30	6.80	5.80	2.55	2.60	1.70	2.00	1.
7	2.70	4.00	4.10	3.00	6.30	6.70	5.40	2.50	2.30	1.70	2.10	1.
8	3.00	4.10	4.05	3.10	6.60	6.65	5.15	2.50	2.30	1.70	2.00	1.
9	3.25	3.90	3.95	3.20	6.30	6.60	5.05	2.40	2.25	1.70	2.10	1.
10	3.45	4.00	3.85	3.30	6.30	6.40	5.00	2.40	2.25	1.80	2.00	1.
11	3.70	3.95	3.65	3.45	6.30	6.30	5.20	2.40	2.40	1.80	2.10	1.
12	3.80	3.75	3.45	3.70	6.30	6.35	5.10	2.40	2.30	1.80	2.10	1.
13	4.00	3.65	3.25	4.10	6.10	6.45	5.00	2.40	2.20	1.90	2.10	1.
14	3.90	3.55	3.20	4.45	6.30	6.55	5.10	2.40	2.20	1.90	2.05	1.
15	4.00	3.60	3.20	4.60	6.30	6.65	5.00	2.40	2.10	1.90	1.30	1.
16	4.10	3.70	3.15	4.90	6.40	6.75	4.90	2.40	2.10	1.90	1.30	1.
17	3.95	3.80	3.10	5.25	6.50	6.80	5.00	2.40	2.00	1.90	1.40	1.
18	3.95	3.60	3.05	5.45	6.40	6.90	4.85	2.40	2.00	1.90	1.30	1.
19	4.10	3.70	3.00	5.65	6.30	6.95	4.55	2.40	2.00	1.90	1.20	1.
20	4.00	3.70	3.00	5.85	6.30	7.00	4.40	2.50	2.00	1.90	1.30	1.
21	3.90	3.70	3.00	6.05	6.20	7.10	4.30	2.40	1.90	1.90	1.20	1.
22	4.00	3.80	3.00	6.20	6.30	7.20	4.20	2.40	1.90	2.00	1.20	1.
23	4.05	3.80	3.00	6.30	6.40	7.35	4.10	2.40	1.85	2.00	1.20	1.
24	4.00	3.90	3.00	6.25	6.35	7.60	4.00	2.40	1.80	2.00	1.30	1.
25	4.10	3.90	3.00	6.15	6.35	7.90	3.90	2.40	1.75	2.00	1.30	1.
26	3.95	3.90	3.00	6.05	6.40	7.75	3.80	2.40	1.70	2.00	1.30	1.
27	3.95	3.90	3.05	5.90	6.30	7.55	3.70	2.35	1.55	2.00	1.30	1.
28	4.10	4.00	3.35	6.00	6.40	7.50	3.50	2.30	1.40	2.00	1.40	1.
29	3.95	.....	3.50	6.10	6.40	7.40	3.25	2.30	1.40	2.00	1.50	1.
30	4.00	.....	3.40	6.20	6.45	7.30	3.15	2.30	1.45	2.00	1.50	1.
31	4.00	.....	3.30	.....	6.55	.....	3.05	2.20	.....	2.00	.....	1.

e height, in feet, of Grand River, left channel, rod No. 2, at Grand Junction, Colorado, for 1898.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
..	4.00	.....	.....	.....	6.05	7.70	6.45	3.60	3.20	3.00	3.30	3.40
..	.....	.....	.....	3.60	5.80	7.90	6.40	3.50	3.30	3.00	3.30	3.40
..	.....	.....	.....	.....	5.45	8.30	6.25	3.50	3.30	3.00	3.30	3.30
..	.....	.....	.....	.....	5.30	8.60	6.00	3.40	3.30	3.00	3.30	.....
..	4.40	.....	3.90	.....	5.30	8.35	5.75	3.30	3.30	3.00	3.30	.....
..	.....	.....	.....	.....	5.30	7.95	5.60	3.30	3.30	3.00	3.30	.....
..	.....	.....	.....	.....	5.20	7.80	5.50	3.30	3.30	3.00	3.30	3.10
..	4.70	.....	.....	.....	5.20	7.90	5.40	3.30	3.25	3.00	3.30	.....
..	.....	.....	.....	4.10	5.20	7.85	5.40	3.30	3.20	3.00	3.30	.....
..	.....	.....	.....	.....	5.10	7.60	5.40	3.40	3.20	3.10	3.30	2.90
..	.....	.....	.....	.....	5.25	7.70	5.30	3.35	3.20	3.20	3.20	.....
..	4.10	.....	3.80	.....	5.65	7.85	5.30	3.30	3.20	3.20	3.20	.....
..	.....	.....	.....	.....	5.85	7.75	5.45	3.30	3.20	3.20	3.20	3.00
..	.....	.....	.....	.....	6.25	7.75	5.75	3.30	3.20	3.15	3.10	.....
..	4.20	.....	.....	.....	6.45	7.85	5.60	3.30	3.20	3.10	3.10	.....
..	.....	.....	.....	4.60	6.35	8.15	5.35	3.20	3.20	3.20	3.10	.....
..	.....	.....	.....	.....	6.30	8.40	5.15	3.20	3.20	3.30	3.10	3.00
..	.....	.....	.....	.....	6.20	8.50	4.95	3.20	3.20	3.30	3.20	.....
..	4.10	4.50	3.70	.....	6.20	8.60	4.80	3.20	3.15	3.30	3.20	.....
..	.....	.....	.....	.....	6.20	8.45	4.65	3.20	3.10	3.30	3.20	.....
..	.....	.....	.....	.....	6.05	8.35	4.45	3.20	3.10	3.30	3.30	3.10
..	4.10	.....	.....	.....	5.90	8.10	4.40	3.20	3.10	3.30	3.40	.....
..	.....	.....	.....	5.10	5.85	8.15	4.20	3.20	3.10	3.30	3.40	.....
..	.....	.....	.....	.....	6.20	8.15	4.15	3.20	3.10	3.30	3.30	3.20
..	.....	.....	.....	5.10	6.55	7.90	4.05	3.30	3.10	3.30	3.30	.....
..	4.00	3.80	3.80	.....	7.05	7.65	4.00	3.40	3.10	3.30	3.30	.....
..	.....	.....	.....	.....	7.20	7.40	4.00	3.30	3.10	3.30	3.30	3.10
..	.....	.....	.....	.....	7.40	7.10	3.85	3.20	3.10	3.30	3.30	.....
..	.....	.....	.....	.....	7.70	6.85	3.80	3.20	3.05	3.30	3.30	.....
..	.....	.....	.....	6.20	7.70	6.65	3.70	3.20	3.00	3.30	3.40	.....
..	.....	.....	.....	.....	7.60	.....	3.60	3.20	.....	3.30	.....	4.00

e height, in feet, of Grand River, right channel, rod No. 1, at Grand Junction, Colorado, for 1898.

May.	June.	July.	Day.	May.	June.	July.	Day.	May.	June.	July.
.....	0.70	0.00	12....	.....	0.85	.....	23....	0.00	1.15	.....
.....	.90	.00	13....	.....	.75	.....	24....	.00	1.15	.....
.....	1.30	.....	14....	.....	.75	.....	25....	.00	.90	.....
.....	1.60	.....	15....	.....	.85	.....	26....	.10	.65	.....
.....	1.35	.....	16....	.....	1.15	.....	27....	.20	.30	.....
.....	.95	.....	17....	.....	1.40	.....	28....	.40	.00	.....
.....	.80	.....	18....	.....	1.50	.....	29....	.70	.00	.....
.....	.90	.....	19....	.....	1.60	.....	30....	.70	.00	.....
.....	.85	.....	20....	.....	1.45	.....	31....	.60	.00	.....
.....	.60	.....	21....	.....	1.35	.....				
.....	.70	.....	22....	0.00	1.15	.....				

Daily gage height, in feet, of Uncompahgre River at Fort Crawford, Colorado for 1898.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	.....	4.60	4.75	4.95	3.75	3.80	3.70	3.75
2	.....	4.60	5.00	4.95	3.65	3.85	3.70	3.75
3	.....	4.15	5.00	4.95	3.50	3.90	3.70	3.75
4	.....	4.20	4.95	4.85	3.70	3.90	3.70	3.70
5	.....	4.15	4.85	4.90	3.70	3.90	3.70	3.80
6	.....	4.10	4.95	4.95	3.70	3.80	3.70	3.75
7	.....	4.10	5.25	4.95	3.70	3.85	3.70	3.70
8	.....	4.00	5.05	4.85	3.70	3.75	3.70	3.75
9	.....	3.95	5.00	4.85	3.70	3.75	3.70	3.75
10	3.60	3.95	4.95	4.80	3.70	3.65	3.70	3.85
11	3.70	3.90	4.95	4.55	3.70	3.65	3.70	3.70
12	3.35	4.00	4.80	4.95	3.70	3.80	3.70	3.65
13	3.80	3.90	4.55	5.05	3.70	3.85	3.70	3.65
14	4.35	4.05	4.95	5.05	3.70	3.85	3.70	3.65
15	4.40	4.05	5.05	5.55	3.70	3.85	3.70	3.60
16	4.40	4.05	5.05	5.45	3.90	3.85	3.70	3.65
17	4.40	4.00	5.55	4.80	4.05	3.85	3.75	3.65
18	4.25	4.05	5.45	4.55	4.00	3.75	3.80	3.65
19	4.15	4.05	5.45	4.35	4.00	3.70	3.75	3.65
20	4.40	4.05	5.45	4.35	4.10	3.70	3.75	3.65
21	4.35	4.00	5.60	4.35	4.15	3.70	3.80	3.70
22	4.35	4.05	5.55	4.20	4.10	3.70	3.70	3.75
23	4.25	4.30	5.65	4.25	4.00	3.70	3.75	3.70
24	4.15	4.40	5.75	4.05	4.15	3.70	3.75	3.65
25	4.40	4.35	5.70	4.05	4.15	3.70	3.75	3.80
26	4.60	4.45	5.45	3.85	4.25	3.70	3.75	3.90
27	4.65	4.45	4.60	3.95	4.25	3.70	3.85	3.85
28	4.60	4.50	5.00	3.95	4.00	3.70	3.85	3.80
29	4.65	4.60	5.05	3.80	3.90	3.70	3.85	3.70
30	4.45	4.75	5.05	3.85	3.75	3.70	3.80	3.75
31	.....	4.65	.....	3.65	3.65	.....	3.85	.....

Approximated from August 4 to August 14 and from September 21 to October 8, inclusive.

Daily gage height, in feet, of Gunnison River at Grand Junction, Colorado, for 1898.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	4.80	5.40	4.10	1.90	1.50	1.30	1.60
2	4.60	5.40	4.10	1.80	1.50	1.30	1.60
3	4.40	5.80	4.00	1.80	1.50	1.30	1.60
4	4.30	5.90	3.70	1.70	1.50	1.30	1.60
5	4.20	5.70	3.50	1.60	1.50	1.30	1.60
6	4.20	5.40	3.40	1.60	1.50	1.30	1.60
7	4.10	5.40	3.60	1.60	1.50	1.30	1.60
8	4.20	5.50	3.80	1.60	1.40	1.30	1.60
9	4.20	5.50	3.70	1.80	1.40	1.30	1.60
10	4.20	5.30	3.70	1.70	1.40	1.30	1.60
11	4.20	5.20	3.60	1.70	1.40	1.40	1.50
12	4.40	5.20	3.50	1.70	1.40	1.40	1.30
13	4.60	5.20	3.50	1.70	1.40	1.40	1.30
14	4.70	5.30	3.50	1.60	1.40	1.40	1.20
15	4.90	5.30	3.40	1.60	1.40	1.40	1.20
16	4.70	5.30	3.20	1.60	1.40	1.40	1.20
17	4.50	5.60	3.20	1.50	1.40	1.40	1.20
18	4.40	5.80	3.20	1.50	1.40	1.50	1.20
19	4.30	5.90	3.10	1.50	1.40	1.50	1.20
20	4.40	5.70	2.90	1.50	1.40	1.50	1.30
21	4.50	5.70	2.80	1.60	1.30	1.60	1.40
22	4.30	5.50	2.70	1.60	1.30	1.60	1.40
23	4.30	5.40	2.60	1.60	1.30	1.60	1.30
24	4.60	5.60	2.60	1.50	1.30	1.60	1.30
25	4.70	5.50	2.50	1.50	1.30	1.60	1.30
26	4.80	5.20	2.50	1.60	1.30	1.60	1.30
27	4.80	5.00	2.40	1.60	1.30	1.60	1.30
28	5.00	4.60	2.20	1.60	1.30	1.60	1.40
29	5.10	4.20	2.20	1.50	1.30	1.60	1.40
30	5.20	4.20	2.10	1.50	1.30	1.60	1.50
31	5.40	.....	2.00	1.50	.....	1.60	.....

ge height, in feet, of San Miguel River at Fallcreek, Colorado, for 1898.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
.....	.....	3.30	4.15	4.25	2.75	2.70	2.50	2.30
.....	.....	3.10	4.25	4.00	2.70	2.70	2.50	2.35
.....	.....	3.10	4.20	3.95	2.70	2.70	2.40	2.35
.....	.....	3.20	4.25	3.90	2.75	2.70	2.40	2.35
.....	.....	3.15	4.15	4.30	2.85	2.70	2.40	2.35
.....	.....	3.15	4.20	4.25	2.90	2.70	2.50	2.30
.....	.....	3.05	4.40	4.00	3.00	2.75	2.45	2.30
.....	.....	3.20	4.40	4.05	3.00	2.70	2.45	2.30
.....	.....	3.20	4.15	3.95	2.90	2.70	2.50	2.30
.....	.....	3.20	4.10	3.90	2.90	2.70	2.50	2.30
.....	3.10	3.30	4.05	3.80	2.90	2.70	2.40	2.40
.....	3.25	3.35	4.00	3.85	2.80	2.65	2.40	2.40
.....	3.25	3.45	4.05	3.80	2.90	2.60	2.40	2.40
.....	3.30	3.45	4.00	3.75	2.90	2.60	2.40	2.40
.....	3.30	3.40	4.30	3.70	2.90	2.55	2.40	2.35
.....	3.25	3.40	4.55	3.60	2.80	2.55	2.40	2.40
.....	3.25	3.30	4.70	3.55	2.80	2.55	2.40	2.30
.....	3.05	3.30	4.55	3.35	2.75	2.55	2.40	2.30
.....	3.05	3.30	4.65	3.30	2.70	2.55	2.40	2.30
.....	3.15	3.20	4.55	3.20	2.75	2.50	2.40	2.30
.....	3.20	3.20	4.60	3.20	2.70	2.50	2.40	2.25
.....	3.05	3.25	4.85	3.05	2.75	2.55	2.40	2.25
.....	3.15	3.45	5.05	3.00	2.80	2.60	2.40	2.30
.....	3.20	3.40	4.55	3.00	2.80	2.60	2.40	2.30
.....	3.35	3.50	4.55	3.00	2.75	2.55	2.40	2.40
.....	3.55	3.40	4.50	3.00	2.70	2.60	2.40	2.40
.....	3.75	3.50	4.35	2.90	2.70	2.50	2.40	2.50
.....	3.60	3.60	4.30	2.85	2.70	2.50	2.40	2.50
.....	3.60	3.80	4.25	2.80	2.70	2.50	2.35	2.50
.....	3.40	3.95	4.20	2.80	2.80	2.50	2.35	2.50
.....	.....	3.90	.....	2.70	2.70	.....	2.30	.....

gage height, in feet, of Mancos River at Mancos, Colorado, for 1898.

Apr.	May.	June	July.	Aug.	Sept.	Day.	Apr.	May.	June	July.	Aug.	Sept.
.....	2.50	2.45	1.80	1.20	1.20	17	2.70	2.05	2.15	1.90	1.10	1.00
.....	2.50	2.45	1.70	1.10	1.10	18	2.70	2.00	2.40	1.70	1.10	1.10
.....	2.40	2.50	1.60	1.10	1.10	19	2.70	2.10	2.15	1.60	1.10	1.10
.....	2.40	2.35	2.60	1.10	1.10	20	2.55	2.40	2.40	1.60	1.10	1.10
.....	2.60	2.40	2.70	1.20	1.10	21	2.55	2.00	2.40	1.60	1.10	1.10
.....	2.50	2.40	2.90	1.20	1.10	22	2.50	2.00	2.40	1.60	1.10	1.10
.....	2.30	2.35	2.50	1.10	1.10	23	2.40	2.30	2.40	1.60	1.10	1.10
.....	2.30	2.30	2.10	1.10	1.10	24	2.60	2.00	2.70	1.40	1.15	1.10
.....	2.20	2.30	2.10	1.10	1.00	25	2.70	2.10	2.40	1.20	1.20	.90
1.90	2.20	2.25	2.20	1.10	1.00	26	2.70	2.30	2.40	.80	1.20	.90
2.00	2.20	2.20	2.10	1.10	1.00	27	2.70	2.30	2.40	.80	1.20	.90
2.00	2.30	2.25	2.00	1.10	1.00	28	2.50	2.30	2.30	.70	1.10	.90
2.40	2.30	2.20	1.90	1.10	1.00	29	2.75	2.30	2.20	.70	1.10	.80
3.10	3.30	2.20	1.80	1.10	1.00	30	2.80	2.50	2.00	.70	1.10	.80
2.80	2.30	2.20	1.80	1.10	1.00	31	.....	2.50	.....	1.20	1.20	.....
2.70	2.20	2.15	1.90	1.10	1.00							

Daily gage height, in feet, of Dolores River at Dolores, Colorado, for 18

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	3.00	4.25	4.85	3.50	2.90	2.80	2.50
2	3.00	4.10	5.10	3.65	2.85	3.15	2.50
3	3.00	4.15	5.00	3.50	2.85	2.95	2.50
4	3.00	4.10	4.90	3.50	2.80	2.90	2.50
5	3.00	4.20	4.80	4.30	2.85	2.80	2.50
6	3.00	4.15	4.80	4.05	2.80	2.80	2.50
7	3.05	4.10	4.80	4.05	2.80	2.80	2.50
8	3.10	4.20	4.80	3.85	2.85	2.80	2.50
9	3.45	4.10	4.50	3.80	2.85	2.70	2.50
10	3.75	4.15	4.35	3.75	2.85	2.70	2.50
11	3.80	4.25	4.55	3.90	2.80	2.70	2.50
12	4.00	4.25	4.45	3.80	2.80	2.70	2.50
13	4.25	4.25	4.45	3.65	2.80	2.70	2.50
14	4.60	4.40	4.50	3.50	2.80	2.70	2.50
15	4.85	4.25	4.55	3.40	2.85	2.70	2.50
16	4.90	4.15	4.70	3.35	2.80	2.70	2.50
17	4.85	4.10	4.90	3.30	2.80	2.70	2.50
18	4.70	4.05	4.95	3.30	2.80	2.70	2.50
19	4.60	4.05	4.60	3.20	2.80	2.60	2.50
20	4.50	4.05	4.60	3.20	2.80	2.60	2.50
21	4.50	3.95	4.60	3.10	2.90	2.60	2.60
22	4.30	4.15	4.70	3.00	2.80	2.60	2.60
23	4.40	4.40	5.00	2.95	2.85	2.60	2.60
24	4.50	4.35	4.70	3.05	3.00	2.60	2.55
25	4.75	4.35	4.35	3.05	3.05	2.50	2.50
26	4.90	4.35	4.10	3.00	2.90	2.50	2.50
27	5.05	4.45	4.10	3.00	2.90	2.50	2.50
28	4.80	4.55	4.00	3.00	2.85	2.50	2.50
29	4.70	4.80	3.95	2.95	2.80	2.50	2.60
30	4.35	4.95	3.80	2.90	2.80	2.50	2.60
31	.....	4.80	.....	2.90	2.80	.....	2.60

Daily gage height, in feet, of San Juan River at Arboles, Colorado, for

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	6.15	7.70	8.15	7.05	6.20	6.10	5.80
2	6.30	7.60	8.45	7.00	6.20	6.00	5.80
3	6.80	7.45	8.45	6.90	6.20	6.00	5.80
4	6.75	7.45	8.35	6.65	6.20	6.00	5.80
5	6.55	7.60	8.15	7.20	6.20	5.90	5.80
6	6.55	7.80	8.10	7.70	6.20	5.90	5.80
7	6.65	7.65	8.15	7.70	6.20	5.90	5.80
8	6.85	7.55	8.10	7.20	6.20	5.90	5.80
9	6.75	7.60	7.90	7.05	6.20	5.90	6.10
10	6.85	7.55	7.65	7.00	6.20	5.90	6.00
11	7.10	7.60	7.60	7.10	6.20	5.90	5.90
12	7.35	7.75	7.70	7.70	6.20	5.90	5.90
13	7.25	7.80	7.90	8.10	6.20	5.90	5.90
14	7.55	7.90	7.85	7.35	6.20	5.90	5.90
15	7.90	7.75	8.00	7.55	6.20	5.90	5.90
16	7.80	7.65	8.25	7.30	6.20	5.90	5.90
17	7.80	7.45	8.35	7.50	6.20	5.90	5.90
18	7.55	7.25	8.25	7.30	6.20	5.90	5.80
19	7.50	7.20	8.30	6.95	6.20	5.90	5.80
20	7.45	7.25	8.20	6.90	6.20	5.90	5.80
21	7.45	7.15	8.20	6.85	6.15	5.90	5.80
22	7.45	7.15	8.05	6.70	6.10	5.90	5.80
23	7.55	7.35	7.95	6.65	6.15	5.90	5.80
24	7.55	7.55	8.55	6.55	6.40	5.90	5.80
25	8.90	7.50	7.90	6.50	6.45	5.80	5.80
26	8.15	7.50	7.65	6.50	6.15	5.80	5.80
27	8.35	7.80	7.45	6.50	6.00	5.80	5.80
28	8.25	8.20	7.25	6.45	6.00	5.80	5.80
29	8.00	8.45	7.15	6.35	5.90	5.80	5.80
30	7.80	8.35	7.10	6.30	5.90	5.80	5.80
31	.....	8.15	.....	6.30	6.20	.....	5.80

Daily gage height, in feet, of Piedra River at Arboles, Colorado, for 1898.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	3.55	4.70	5.15	4.00	3.15	3.00	2.60	2.60
2	4.25	4.65	5.40	3.95	3.05	3.00	2.60	2.60
3	4.80	4.45	5.45	3.80	3.00	3.00	2.60	2.60
4	4.10	4.45	5.30	3.60	2.90	2.90	2.60	2.60
5	3.90	4.60	5.15	4.35	2.90	2.80	2.60	2.60
6	3.80	4.70	5.10	4.85	2.90	2.80	2.60	2.60
7	4.00	4.60	5.15	4.75	2.90	2.80	2.60	2.60
8	4.15	4.60	5.10	4.20	2.90	2.80	2.60	2.60
9	3.85	4.60	4.90	4.05	2.90	2.80	3.00	2.60
10	3.95	4.55	4.65	4.00	2.90	2.80	2.90	2.60
11	4.25	4.60	4.60	4.10	2.90	2.70	2.80	2.60
12	4.50	4.75	4.60	4.60	2.90	2.70	2.80	2.60
13	4.60	4.80	4.80	5.20	2.90	2.70	2.80	2.50
14	4.85	4.80	4.85	4.50	2.90	2.70	2.80	2.50
15	5.10	4.70	5.05	4.40	2.90	2.70	2.80	2.50
16	5.00	4.65	5.30	4.30	2.90	2.70	2.70	2.50
17	5.00	4.45	5.35	4.30	2.90	2.70	2.70	2.50
18	4.80	4.25	5.30	4.10	2.90	2.70	2.70	2.50
19	4.80	4.20	5.30	3.90	2.90	2.70	2.60	2.50
20	4.75	4.15	5.00	3.80	2.90	2.70	2.60	2.50
21	4.70	4.05	5.05	3.75	2.85	2.70	2.60	2.50
22	4.65	4.10	4.95	3.55	2.80	2.70	2.60	2.50
23	4.60	4.25	5.20	3.50	2.80	2.70	2.60	2.50
24	4.60	4.40	5.10	3.45	3.10	2.70	2.60	2.50
25	5.00	4.30	4.90	3.40	3.25	2.60	2.60	2.50
26	5.35	4.30	4.65	3.30	3.10	2.60	2.60	2.50
27	5.50	4.60	4.40	3.30	3.00	2.60	2.60	2.50
28	5.40	5.00	4.25	3.30	3.00	2.60	2.60	2.50
29	5.10	5.35	4.15	3.25	2.90	2.60	2.60	2.50
30	4.75	5.45	4.05	3.20	2.90	2.60	2.60	2.50
31	.....	5.10	.....	3.20	3.10	.....	2.60	.....

Daily gage height, in feet, of Animas River at Durango, Colorado, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	5.50	5.30	5.00	5.25	7.05	8.60	7.55	5.40	5.10	4.70	4.70
2	.....	.....	.....	5.35	6.85	9.00	7.35	5.30	5.30	4.70	4.70
3	.....	.....	.....	5.45	6.60	8.90	7.10	5.30	5.25	4.70	4.70
4	5.20	.....	.....	5.45	6.70	8.70	7.00	5.20	5.20	4.70	4.70
5	.....	5.00	5.10	5.40	6.60	8.55	7.80	5.20	5.10	4.70	4.70
6	.....	.....	.....	5.45	6.60	8.65	8.40	5.20	5.10	4.70	4.70
7	.....	.....	.....	5.50	6.80	8.80	7.80	5.20	5.10	4.70	4.70
8	5.00	5.00	5.00	5.60	6.90	9.00	7.65	5.20	5.05	4.70	4.70
9	.....	.....	.....	5.90	6.85	8.35	7.55	5.20	5.05	4.70	4.70
10	.....	.....	.....	6.45	7.00	8.10	7.25	5.20	5.00	4.70	4.70
11	5.30	.....	.....	6.60	7.30	8.00	7.25	5.20	5.00	4.75	4.70
12	.....	4.80	5.00	6.45	7.40	7.95	7.10	5.15	5.00	4.75	4.70
13	.....	.....	.....	6.60	7.45	7.85	6.95	5.15	5.00	4.75	4.70
14	.....	.....	.....	7.30	7.50	8.40	6.70	5.10	5.00	4.70	4.70
15	5.10	4.80	.....	7.65	7.40	8.35	6.75	5.10	4.90	4.70	4.70
16	.....	.....	5.00	7.60	7.15	8.65	6.60	5.10	4.90	4.70	4.70
17	.....	.....	.....	7.55	6.95	9.05	6.50	5.05	4.90	4.70	4.70
18	5.20	.....	.....	7.60	6.65	8.80	6.35	5.10	4.95	4.70	4.65
19	.....	4.90	5.00	7.25	6.60	8.80	6.20	5.05	4.95	4.70	4.60
20	.....	.....	.....	7.05	6.65	8.65	6.10	5.10	4.90	4.70	4.65
21	.....	.....	.....	7.20	6.55	8.55	6.00	5.10	4.80	4.70	4.60
22	5.10	.....	5.10	6.90	6.60	8.65	5.90	5.10	4.90	4.70	4.70
23	.....	4.90	.....	7.15	6.90	9.15	5.75	5.10	4.80	4.70	4.85
24	.....	.....	.....	7.40	7.05	8.90	5.70	5.20	4.80	4.70	4.80
25	5.30	.....	.....	7.60	7.15	8.60	5.70	5.20	4.80	4.70	4.80
26	.....	5.00	5.20	7.85	7.05	8.30	5.70	5.20	4.80	4.70	4.75
27	.....	.....	.....	8.20	7.30	8.10	5.60	5.20	2.80	4.70	4.65
28	.....	.....	.....	8.00	7.80	7.60	5.60	5.20	4.70	4.70	4.60
29	5.30	.....	5.10	7.70	8.35	7.75	5.55	5.10	4.70	4.70	4.60
30	.....	.....	.....	7.25	8.65	7.55	5.40	5.10	4.70	4.70	4.65
31	.....	.....	.....	.....	8.20	.....	5.40	5.10	.....	4.70	.....

Daily gage height, in feet, of Gila River at Buttes, Arizona, for 1898.

Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.
1	.....	2.35	9	.....	2.50	17	.....	2.80	25	2.10	.....
2	.....	2.35	10	.....	.....	18	.....	2.85	26	2.20	2.80
3	.....	2.35	11	.....	2.60	19	.....	2.90	27	2.20	2.80
4	.....	2.40	12	.....	2.75	20	.....	2.90	28	2.10	2.85
5	.....	2.40	13	.....	2.50	21	.....	2.90	29	2.25	2.75
6	.....	2.40	14	.....	2.70	22	.....	2.90	30	2.30	2.80
7	.....	2.45	15	.....	2.75	23	.....	2.90	31	.....	2.80
8	.....	2.45	16	.....	2.75	24	.....	2.95			

Daily gage height, in feet, of Salt River at McDowell, Arizona, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	10.10	11.20	11.30	10.80	11.30	10.20	9.90	11.50	12.00	10.35	10.45	10.60
2	10.10	11.00	11.40	10.80	11.30	10.20	9.90	11.30	12.50	10.35	10.45	10.60
3	10.10	10.90	11.50	10.80	11.20	10.20	9.85	10.95	11.90	10.35	10.45	10.60
4	10.10	10.90	11.50	10.80	11.15	10.15	9.85	10.90	11.50	10.35	10.45	10.60
5	10.10	10.95	11.50	10.90	11.10	10.10	9.95	10.90	11.40	10.35	10.45	10.60
6	10.10	10.95	11.35	11.00	11.05	10.10	11.00	10.90	11.50	10.35	10.50	10.60
7	10.10	10.90	11.30	11.00	11.00	10.10	10.60	10.95	11.10	10.35	10.50	10.60
8	10.10	11.00	11.30	11.00	11.00	10.10	11.00	10.90	11.00	10.35	10.50	10.60
9	10.10	11.10	11.30	11.05	10.95	10.05	10.90	10.90	11.00	10.35	10.50	10.65
10	10.15	11.30	11.30	11.40	10.90	10.05	10.40	10.90	10.95	10.35	10.50	10.65
11	10.30	11.35	11.40	11.40	10.80	10.10	10.35	10.90	10.80	10.35	10.50	10.90
12	10.40	11.00	11.70	11.70	10.70	10.05	10.60	10.80	11.10	10.40	10.45	10.80
13	10.40	10.90	11.60	11.80	10.65	10.05	10.90	10.80	11.00	10.40	10.45	10.85
14	10.30	10.80	11.60	11.70	10.60	10.05	11.00	10.80	10.95	10.35	10.50	10.90
15	10.20	10.70	11.50	11.60	10.50	10.10	11.30	10.75	10.85	10.40	10.50	10.80
16	10.20	10.70	11.50	11.60	10.50	10.10	11.75	10.85	10.85	10.35	10.50	10.80
17	10.20	10.75	11.40	11.75	10.50	10.05	11.75	10.70	10.80	10.35	10.50	11.00
18	10.20	10.80	11.30	12.00	10.45	10.05	12.20	10.80	10.70	10.35	10.50	11.00
19	10.20	10.90	11.30	12.10	10.50	10.00	11.50	10.90	10.60	10.35	10.50	11.10
20	10.20	10.90	11.20	12.20	10.50	10.00	12.30	10.80	10.55	10.40	10.50	11.10
21	10.15	11.00	11.20	12.25	10.40	10.00	12.10	10.80	10.55	10.40	10.50	11.05
22	10.15	11.00	11.15	12.10	10.40	10.00	11.80	10.80	10.50	10.40	10.55	11.00
23	10.15	11.00	11.10	12.00	10.40	10.40	11.50	10.80	10.60	10.40	10.55	10.90
24	10.15	10.95	11.00	11.90	10.30	10.30	12.00	10.30	10.60	10.40	10.55	10.90
25	10.15	10.95	11.00	11.80	10.30	10.20	11.80	11.00	10.50	10.40	10.55	10.90
26	10.15	11.40	10.95	11.70	10.20	10.20	11.40	11.40	10.45	10.40	10.60	10.80
27	10.10	11.25	10.90	11.60	10.20	10.10	11.10	13.50	10.40	10.45	10.60	10.85
28	11.00	11.30	10.90	11.50	10.20	10.05	11.10	11.60	10.40	10.40	10.60	10.70
29	11.70	.....	10.90	11.40	10.20	10.00	11.00	11.40	10.35	10.40	10.60	10.70
30	12.30	.....	10.85	11.30	10.15	9.95	10.95	11.30	10.35	10.40	10.60	10.75
31	11.50	.....	10.80	.....	10.20	.....	10.80	11.50	.....	10.45	.....	10.85

gage height, in feet, of Verde River at McDowell, Arizona, for 1898.

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
6.70	7.50	7.80	7.15	6.80	6.80	6.70	8.30	8.80	6.80	6.80	7.20
6.70	7.40	7.90	7.15	6.95	6.80	6.70	7.70	8.50	6.80	6.80	7.20
6.75	7.35	8.00	7.20	7.10	6.80	6.70	7.50	8.80	6.80	6.80	7.20
6.75	7.30	8.05	7.30	7.10	6.80	6.70	7.30	7.80	6.75	6.80	7.20
6.75	7.30	8.05	7.40	7.10	6.80	6.65	7.40	7.60	6.75	6.80	7.20
6.75	7.40	7.70	7.35	7.10	6.80	7.15	7.50	7.50	6.80	6.90	7.15
6.75	7.35	7.70	7.30	7.15	6.80	6.95	7.80	7.40	6.80	6.95	7.15
6.75	7.45	7.70	7.30	7.10	6.80	6.90	7.30	7.35	6.80	6.95	7.15
6.75	7.40	7.80	7.30	7.05	6.80	7.20	7.00	7.30	6.80	7.00	7.20
6.85	7.55	7.75	7.30	7.00	6.80	7.10	7.00	7.20	6.80	6.90	7.20
6.95	7.50	7.80	7.35	7.00	6.85	7.00	6.95	7.10	6.80	6.90	7.40
7.05	7.30	8.20	7.30	7.00*	6.85	7.05	7.00	7.05	6.80	6.95	7.45
7.00	7.20	8.00	7.30	7.00	6.85	7.05	6.90	7.00	6.80	6.95	7.55
6.85	7.15	8.00	7.25	6.95	6.85	7.20	6.85	6.95	6.80	7.00	7.50
6.90	7.15	8.05	7.25	6.85	6.85	7.25	6.75	7.10	6.80	7.00	7.45
6.85	7.20	7.60	7.20	6.95	6.90	9.45	6.85	7.00	6.80	7.00	7.55
6.85	7.40	7.00	7.15	6.85	6.90	8.20	6.90	7.00	6.80	7.00	7.50
6.85	7.50	7.40	7.15	6.90	6.85	8.35	6.85	7.00	6.80	7.00	7.60
6.80	7.50	7.80	7.15	6.90	6.80	7.90	7.00	7.00	6.80	7.05	7.60
6.80	7.60	7.40	7.15	6.95	6.85	7.50	7.00	6.90	6.80	7.05	7.50
6.85	7.50	7.30	7.15	6.95	6.85	7.30	6.95	6.90	6.80	7.05	7.45
6.85	7.50	7.30	7.15	6.95	6.85	7.10	6.95	6.90	6.85	7.10	7.40
6.85	7.50	7.20	7.10	6.95	6.85	7.00	7.75	6.90	6.85	7.10	7.40
6.85	7.50	7.20	7.10	6.95	6.90	7.00	7.30	6.90	6.90	7.10	7.40
6.85	7.60	7.20	7.10	6.90	6.95	7.00	7.20	6.90	6.90	7.15	7.40
6.85	7.60	7.15	7.05	6.90	6.95	7.00	7.50	6.90	6.90	7.20	7.40
6.85	7.80	7.10	7.05	6.85	6.95	6.95	9.25	6.90	6.90	7.20	7.50
7.10	7.80	7.10	7.05	6.85	6.95	6.95	8.50	6.90	6.90	7.15	7.55
8.10	.....	7.15	7.00	6.85	6.85	6.80	8.40	6.80	6.90	7.20	7.55
8.80	.....	7.15	6.95	6.85	6.80	7.00	7.90	6.80	6.90	7.20	7.45
7.80	.....	7.15	.....	6.80	.....	6.80	7.85	.....	6.90	.....	7.40

gage height, in feet, of Colorado River at Yuma, Arizona, for 1898.

.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Sept.	Oct.	Nov.	Dec.
.....	17.92	18.00	18.92	18.67	21.50	21.58	23.42	19.75	18.00	18.17	18.58
.....	17.83	18.00	19.00	18.67	21.42	21.50	23.42	19.75	18.00	18.25	18.50
.....	17.75	18.25	19.00	18.58	21.42	21.58	23.17	19.83	18.08	18.33	18.42
.....	17.75	18.25	19.00	18.58	21.75	21.75	22.83	19.83	18.00	18.33	18.33
.....	17.58	17.92	18.92	18.83	22.00	22.25	22.58	19.75	18.00	18.50	18.33
.....	17.58	18.00	18.83	18.67	22.00	22.58	22.25	19.83	18.00	18.58	18.33
.....	17.58	17.83	18.75	18.50	22.00	22.75	22.00	19.67	18.00	18.58	18.42
.....	17.50	17.75	18.67	18.50	22.00	22.83	21.83	19.42	18.00	18.50	18.42
.....	17.50	18.00	18.67	18.67	21.75	22.92	21.67	19.17	18.00	18.58	18.58
.....	17.83	18.08	18.75	19.00	21.58	23.17	21.50	19.00	18.00	18.50	18.58
.....	17.75	18.33	19.00	19.08	21.33	23.17	21.33	19.08	18.00	18.50	18.58
.....	17.75	18.17	19.08	18.92	21.25	23.00	21.25	19.00	18.00	18.50	18.50
.....	17.92	18.17	19.25	18.67	21.17	22.92	21.50	18.92	17.92	18.50	18.50
.....	18.08	18.17	19.08	18.50	21.17	22.67	21.50	18.83	17.92	18.50	18.50
.....	18.42	18.25	18.92	18.75	21.17	22.58	21.42	18.83	17.92	18.50	18.50
.....	18.58	18.42	18.75	18.92	21.00	22.50	21.33	18.75	17.92	18.58	18.58
.....	18.75	18.50	18.75	18.83	20.83	22.42	21.50	18.67	17.83	18.67	18.75
.....	18.75	18.58	18.92	18.92	20.83	22.33	21.33	18.58	17.83	18.75	18.92
.....	18.75	18.58	18.92	19.00	20.92	22.42	21.25	18.75	17.83	18.83	19.00
.....	18.83	18.50	18.83	20.08	21.17	22.33	21.08	18.75	17.83	18.83	18.83
.....	18.83	18.58	18.92	20.17	21.50	22.33	21.08	18.58	17.83	18.92	18.67
.....	18.75	18.67	19.17	20.25	21.67	22.50	21.50	18.42	17.83	18.92	18.42
.....	18.50	18.92	19.08	21.17	21.75	22.75	22.00	18.42	17.83	18.92	18.17
.....	18.42	18.92	19.08	21.08	21.75	23.08	21.92	18.42	17.83	18.75	18.00
.....	18.25	18.92	18.83	21.67	21.67	23.25	21.50	18.42	17.83	18.75	17.92
.....	18.42	18.92	18.75	21.75	21.83	23.50	21.17	18.42	18.00	18.75	17.75
.....	18.50	18.92	18.67	21.58	21.75	23.50	21.00	18.33	18.00	18.75	17.67
.....	18.33	18.92	18.67	21.50	21.50	23.50	20.50	18.25	18.08	18.75	17.67
.....	18.17	.....	18.67	21.50	21.50	23.50	20.33	18.17	18.17	18.67	17.58
.....	19.17	.....	18.75	21.50	21.50	23.42	20.17	18.00	18.17	18.67	17.50
.....	18.08	.....	18.67	.....	21.42	.....	20.17	.....	18.17	.....	17.58

ished by United States Commission of Fish and Fisheries.

List of discharge measurements, 1898.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
				Feet.	*Sec.-feet.*
Apr. 29	Black Fork River	Granger, Wyo	C. T. Johnston	3.20	1,962
May 21	do	do	do	2.60	1,727
June 18	do	do	do	3.40	2,401
June 29	do	do	do	2.30	1,328
Apr. 29	Green River	Greenriver, Wyo	do	2.60	3,803
May 21	do	do	do	3.00	a 4,239
Do.	do	do	do	2.95	b 3,966
June 18	do	do	do	4.50	11,696
June 28	do	do	do	5.05	14,252
Apr. 25	Grand River	Grand Junction, Colo.	A. L. Fellows	5.15	4,892
May 23	do	do	do	5.85	6,087
June 27	do	do	do	7.40	11,215
Aug. 27	do	do	do	3.35	1,237
Oct. 15	do	do	do	3.20	949
Apr. 5	Uncompahgre River.	Fort Crawford, Colo.	do	3.55	91
May 9	do	do	do	3.92	263
June 15	do	do	do	5.18	720
Aug. 12	do	do	do	3.80	74
Oct. 16	do	do	do	3.75	56
Apr. 26	Gunnison River	Grand Junction, Colo.	do	4.65	5,932
May 23	do	do	do	4.50	4,647
June 28	do	do	do	4.62	5,274
Aug. 27	do	do	do	1.80	866
Oct. 15	do	do	do	1.50	578
Apr. 7	San Miguel River	Fallcreek, Colo	do	2.50	66
May 11	do	do	do	3.30	270
June 16	do	do	do	4.40	841
Aug. 13	do	do	do	2.80	133
Oct. 17	do	do	do	2.30	30
Apr. 9	Mancos River	Mancos, Colo	do	1.80	102
May 14	do	do	do	2.20	185
June 18	do	do	do	2.00	160
Aug. 20	do	do	do	1.00	5
Oct. 18	do	do	do	.80	3
Apr. 8	Dolores River	Dolores, Colo	do	3.15	325
May 12	do	do	do	4.30	1,163
June 17	do	do	G. H. Matthes	4.80	1,870
Aug. 16	do	do	do	2.80	102
Sept. 11	do	do	do	2.70	72
Sept. 28	do	do	A. L. Fellows	2.55	46
Oct. 21	do	do	do	2.55	40
Apr. 12	San Juan River	Arboles, Colo	do	7.30	1,403
May 17	do	do	do	7.42	1,497
June 21	do	do	do	8.10	2,579
Aug. 8	do	do	G. H. Matthes	6.30	294
Aug. 23	do	do	A. L. Fellows	6.05	213
Oct. 23	do	do	do	5.80	83
Apr. 13	Piedra River	do	do	4.80	1,158
May 16	do	do	do	4.52	937
June 22	do	do	do	5.10	1,315
Aug. 8	do	do	G. H. Matthes	3.10	195
Aug. 24	do	do	A. L. Fellows	3.05	186
Oct. 24	do	do	do	2.60	52
Apr. 11	Animas River	Durango, Colo	do	6.50	1,356
May 15	do	do	do	7.25	1,797
June 20	do	do	do	8.55	3,475
Aug. 5	do	do	G. H. Matthes	5.20	414
Aug. 22	do	do	A. L. Fellows	5.07	284
Oct. 22	do	do	do	4.70	160
Mar. 7	Gila River	Buttes, Ariz	A. T. Colton	2.30	373
Mar. 29	do	do	do	2.50	606
Apr. 12	do	do	do	2.40	291
Apr. 23	do	do	do	3.25	855
May 17	do	do	do	2.50	182
June 8	do	do	do	2.00	27
June 22	do	do	do	2.10	32
July 6	do	do	do	4.55	2,902
July 19	do	do	do	4.00	2,134
July 29	do	do	do	3.15	799
Aug. 8	do	do	do	2.90	590
Aug. 22	do	do	do	2.70	466
Oct. 10	do	do	do	1.90	59
Nov. 14	do	do	C. C. Babb	1.90	94
Nov. 25	do	do	do	2.10	125
Dec. 14	do	do	do	2.70	305
Dec. 24	do	do	do	2.95	382
Nov. 28	Florence Canal	Bridge 2 miles east of Florence.	do		76
Do.	*do*	White's ranch near head gate.	do		100

a 5 a. m. b 2 p. m.

List of discharge measurements, 1898—Continued.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
				Feet.	*Sec.-feet.*
Jan. 8	Salt River	McDowell, Ariz.	W. A. Farish	10.10	288
Jan. 30	do	do	do	12.10	1,064
Feb. 27	do	do	do	11.40	545
Mar. 13	do	do	do	11.57	856
Mar. 20	do	do	do	11.20	688
Apr. 10	do	do	do	11.35	768
Apr. 24	do	do	do	11.90	999
May 28	do	do	do	10.20	295
May 29	do	do	do	10.20	257
June 13	do	do	do	10.10	233
June 26	do	do	do	10.10	296
July 18	do	do	do	12.25	1,057
Aug. 7	do	do	do	10.80	398
Aug. 22	do	do	do	10.70	425
Aug. 29	do	do	do	11.40	650
Sept. 28	do	do	do	10.37	195
Sept. 29	do	do	do	10.37	178
Oct. 27	do	do	do	10.40	186
Oct. 28	do	do	do	10.35	196
Nov. 27	do	do	do	10.55	260
Nov. 28	do	do	do	10.60	229
Dec. 25	do	do	do	10.75	287
Dec. 26	do	do	do	10.70	284
Jan. 7	Verde River	do	do	6.75	323
Jan. 30	do	do	do	8.25	1,868
Mar. 13	do	do	do	8.00	956
Mar. 20	do	do	do	7.40	481
Apr. 10	do	do	do	7.30	332
Apr. 24	do	do	do	7.05	234
May 28	do	do	do	6.85	127
May 29	do	do	do	6.85	130
June 13	do	do	do	6.80	142
June 26	do	do	do	7.00	152
July 18	do	do	do	8.30	991
Aug. 7	do	do	do	7.45	258
Aug. 22	do	do	do	7.00	205
Aug. 29	do	do	do	7.40	592
Sept. 28	do	do	do	6.90	142
Sept. 29	do	do	do	6.80	175
Oct. 27	do	do	do	6.95	209
Oct. 28	do	do	do	6.85	220
Nov. 27	do	do	do	7.20	290
Nov. 28	do	do	do	7.15	287
Dec. 25	do	do	do	7.45	281
Dec. 26	do	do	do	7.40	332

List of miscellaneous discharge measurements, 1898.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
				Feet.	*Sec.-feet.*
Aug. 6	Los Pinos River	6 miles above Ignacio, Colo.	G. H. Matthes		246
Aug. 7	Do	4 miles below Ignacio, Colo.	do		196
Aug. 10	La Plata River	Hesperus, Colo	do		11
Aug. 18	San Juan River	Noland, Utah	do		609
Sept. 14	White River	Meeker, Colo	A. L. Fellows		300
Sept. 15	Williams River	Hamilton, Colo	do		25
Sept. 17	Yampa River	3 miles below Hayden, Colo.	do		111
Do.	Elk River	Near mouth, Trull post-office, Colo.	do		63
Sept. 18	Yampa River	Steamboat Springs, Colo.	do		65
Sept. 19	Snake River	Honnold post-office, Colo.	do		17
Sept. 20	Slater Fork of Snake River.	Slater post-office, Colo.	do		9
Sept. 21	Little Snake River.	Dixon, Wyo	do		19
Do.	San Juan River	Noland, Utah	G. H. Matthes		383
Sept. 22	Yampa River	Below Maybell, Colo.	A. L. Fellows		99
Sept. 24	Green River	6 miles below Ladore, Colo.	do		552
Sept. 26	Yampa River	Craig, Colo	do		79

Rating tables.

[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	
Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge
Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible] Rating table for [illegible] River.
[illegible] Rating table for [illegible] River.

[illegible] Applicable [illegible]

Fort Crawford.		Grand Junction.		Gill Creek.		Hanover.		Delores.	
Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible] June 24 to November 30, 1909.

b Rating table for Gunnison River.

Rating tables—Continued.

›les. *a*	Arboles. *b*		Durango.		McDowell. *c*		McDowell. *d*	
Dis-charge.	Gage height.	Dis-charge.	Gage height.	Dis-charge.	Gage height.	Dis-charge.	Gage height.	Dis-charge.
Sec.-feet.	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*
83	2.5	27	4.6	125	10.0	215	10.0	30
124	2.6	52	4.7	160	10.1	255	10.1	66
169	2.7	78	4.8	195	10.2	296	10.2	102
216	2.8	106	4.9	234	10.3	336	10.3	137
266	2.9	135	5.0	278	10.4	377	10.4	173
319	3.0	165	5.1	328	10.5	417	10.5	209
376	3.1	196	5.2	383	10.6	458	10.6	244
440	3.2	229	5.3	442	10.7	498	10.7	280
510	3.3	264	5.4	502	10.8	539	10.8	316
590	3.4	301	5.5	562	10.9	579	10.9	351
680	3.5	340	5.6	624	11.0	620	11.0	387
795	3.6	382	5.7	686	11.1	660	11.1	423
935	3.7	430	5.8	748	11.2	701	11.2	458
1,082	3.8	478	5.9	812	11.3	741	11.3	494
1,232	3.9	530	6.0	877	11.4	782	11.4	530
1,382	4.0	585	6.2	1,008	11.5	822	11.5	565
1,531	4.1	643	6.4	1,146	11.6	863	11.6	601
1,681	4.2	704	6.6	1,292	11.7	903	11.7	637
1,830	4.3	768	6.8	1,444	11.8	944	11.8	672
1,980	4.4	835	7.0	1,608	11.9	984	11.9	708
2,130	4.5	904	7.2	1,786	12.0	1,025	12.0	744
2,280	4.6	974	7.4	1,975	12.2	1,106	12.1	780
2,429	4.7	1,043	7.6	2,176	12.4	1,187	12.2	816
2,579	4.8	1,112	7.8	2,394	12.6	1,268	12.3	851
2,729	4.9	1,182	8.0	2,638	12.8	1,349	12.4	887
2,879	5.0	1,251	8.2	2,910	13.0	1,430	12.5	923
3,029	5.1	1,321	8.4	3,220	13.2	1,511	12.6	958
3,180	5.2	1,390	8.6	3,570	13.4	1,592	12.7	994
3,330	5.3	1,459	8.8	3,952	13.6	1,673	12.8	1,030
----------	5.4	1,529	9.0	4,358	13.8	1,754	12.9	1,065

a Rating table for San Juan River.
b Rating table for Piedra River.
c Rating table for Salt River; applicable from January 1 to July 5, 1898.
d Rating table for Salt River; applicable from July 6 to December 31, 1898.

INTERIOR BASIN DRAINAGE.

DESCRIPTION OF RIVER STATIONS.

station on North Fork of Humboldt River.—This station is at tral Pacific Railroad bridge, about 2 miles west of Peko sta- evada. It was established by Mr. L. H. Taylor, March 25, The observer is James Courtney, post-office, Halleck, Nevada. ge consists of a vertical timber, divided to feet and tenths, to the pile support of the railroad bridge. The bench mark is stone abutment on the east end of the bridge on the left bank stream, 12 feet above the zero of the gage. The initial point ıdings is on the left bank, at the bench mark. The channel nd below the station is curved and the water is moderately swift. side channel enters immediately above the bridge and another l takes water from the main stream at a still higher point dur- h stages, but during medium and low water it is dry. Meas- ts are made from the upper side of the bridge. The bed of the is of sand and gravel, shifting somewhat during high water.

station on Humboldt River.—Described on page 152 of Paper ; results for 1897 given on pages 424–426 of the Nineteenth

Daily gage height, in feet, of Humboldt River at Golconda, Nevada, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.80	2.60	4.20	3.50	1.40	3.50	2.70	1.00	0.30	0.10	0.20	0.20
2	2.80	2.60	4.20	3.50	1.50	3.50	2.60	.90	.30	.10	.20	.20
3	2.80	2.60	4.20	3.40	1.40	3.60	2.60	.80	.30	.10	.20	.20
4	2.80	2.60	4.20	3.30	1.40	3.70	2.60	.80	.30	.10	.20	.20
5	2.80	2.60	4.15	3.20	1.30	3.70	2.60	.70	.20	.10	.20	.20
6	2.80	2.60	4.15	3.20	1.20	3.70	2.60	.70	.20	.10	.20	.20
7	2.85	2.60	4.15	3.10	1.20	3.70	2.50	.70	.20	.10	.20	.20
8	2.75	2.60	4.15	3.10	1.10	3.70	2.50	.70	.20	.10	.20	.20
9	2.75	2.60	4.20	3.00	1.00	3.60	2.50	.70	.20	.10	.20	.20
10	2.75	2.60	4.30	2.90	.95	3.50	2.50	.60	.20	.10	.20	.20
11	2.70	2.60	4.20	2.90	.90	3.30	2.40	.60	.20	.20	.20	.20
12	2.70	2.60	4.20	2.85	1.00	3.20	2.30	.60	.10	.20	.20	.30
13	2.70	2.60	4.30	2.80	1.30	3.00	2.30	.60	.10	.20	.20	.40
14	2.70	2.60	4.40	2.70	1.40	2.90	2.20	.60	.10	.20	.20	.50
15	2.75	2.70	4.50	2.60	1.50	2.80	2.10	.60	.00	.20	.20	.50
16	2.75	2.80	4.50	2.50	1.50	2.70	2.10	.50	.00	.20	.20	.60
17	2.75	3.00	4.50	2.50	1.60	2.70	2.10	.50	.00	.20	.20	.60
18	2.70	3.20	4.50	2.40	1.60	2.60	1.90	.40	.00	.20	.20	.60
19	2.70	3.40	4.20	2.30	1.50	2.50	1.80	.40	.00	.20	.20	.60
20	2.70	3.50	4.00	2.20	1.50	2.50	1.70	.40	.00	.20	.20	.60
21	2.70	3.50	4.00	2.00	1.50	2.50	1.60	.40	.00	.20	.20	.60
22	2.70	3.70	3.90	2.00	1.50	2.50	1.60	.40	.00	.20	.20	.60
23	2.60	3.90	3.90	2.10	1.50	2.50	1.50	.40	.00	.20	.20	.60
24	2.60	4.00	3.90	2.10	1.60	2.50	1.50	.40	.00	.20	.20	.70
25	2.60	4.20	3.85	2.10	2.10	2.50	1.50	.40	.00	.20	.20	.70
26	2.60	4.30	3.85	2.00	2.60	2.60	1.40	.30	.00	.20	.20	.70
27	2.60	4.20	3.80	1.90	2.80	2.60	1.30	.30	.00	.20	.20	.80
28	2.60	4.20	3.80	1.70	3.00	2.60	1.20	.30	.00	.20	.20	.70
29	2.60	.....	3.75	1.50	3.10	2.70	1.10	.30	.00	.20	.20	.70
30	2.60	.....	3.70	1.50	3.40	2.70	1.00	.30	.00	.20	.20	.70
31	2.60	.....	3.60	.....	3.50	.....	1.00	.30	.....	.20	.....	.70

Daily gage height, in feet, of Humboldt River at Oreana, Nevada, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	Day.	Jan.	Feb.	Mar.	Apr.	May.	June.
1	3.10	3.10	4.10	3.30	1.80	1.30	17	3.20	3.20	3.90	2.50	1.45	1.50
2	3.10	3.10	4.20	3.20	1.70	1.30	18	3.20	3.25	3.80	2.40	1.45	1.41
3	3.10	3.10	4.20	3.20	1.65	1.25	19	3.15	3.30	3.60	2.35	1.45	1.35
4	3.10	3.10	4.30	3.20	1.60	1.25	20	3.15	3.30	3.50	2.30	1.45	1.30
5	3.10	3.10	4.40	3.20	1.60	1.25	21	3.15	3.35	3.40	2.30	1.40	1.30
6	3.15	3.10	4.50	3.10	1.60	1.25	22	3.15	3.40	3.30	2.25	1.40	1.30
7	3.15	3.10	4.50	3.10	1.55	1.25	23	3.10	3.50	3.30	2.20	1.40	1.30
8	3.20	3.10	4.50	3.10	1.55	1.25	24	3.10	3.60	3.20	2.10	1.35	1.30
9	3.15	3.10	4.60	3.00	1.50	1.25	25	3.10	3.80	3.20	2.05	1.35	1.25
10	3.15	3.10	4.60	2.90	1.50	1.25	26	3.10	4.00	3.20	2.00	1.30	1.25
11	3.15	3.10	4.50	2.85	1.50	1.25	27	3.10	4.00	3.20	2.00	1.30	1.25
12	3.10	3.10	4.50	2.85	1.50	1.25	28	3.10	4.00	3.20	1.95	1.30	1.25
13	3.10	3.10	4.45	2.80	1.50	1.25	29	3.10	.....	3.30	1.90	1.30	1.25
14	3.10	3.10	4.40	2.70	1.50	1.30	30	3.10	.....	3.30	1.85	1.30	1.20
15	3.15	3.15	4.20	2.60	1.50	1.40	31	3.10	.....	3.30	.....	1.30	.....
16	3.15	3.15	4.00	2.55	1.50	1.60							

Daily gage height, in feet, of South Fork of Humboldt River at Masons Ranch, Nevada, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	0.90	1.30	1.50	1.25	2.10	2.45	1.80	0.45	0.30	0.40	0.65	0.90
2	.85	1.30	1.45	1.25	2.00	2.30	1.80	.45	.30	.45	.65	.90
3	.85	1.20	1.45	1.25	2.00	2.35	1.70	.45	.30	.45	.65	.90
4	.85	1.20	1.40	1.25	1.95	2.30	1.60	.45	.35	.45	.65	.80
5	.85	1.20	1.40	1.20	1.90	2.35	1.45	.45	.35	.45	.65	.70
6	.85	1.25	1.35	1.20	1.80	2.20	1.35	.40	.35	.45	.65	.70
7	1.00	1.30	1.35	1.25	1.75	2.15	1.35	.40	.35	.45	.65	.70
8	1.00	1.30	1.35	1.25	1.70	2.25	1.30	.40	.35	.45	.65	.70
9	1.00	.95	1.35	1.20	1.70	2.35	1.30	.40	.35	.50	.65	.70
10	1.10	1.30	1.30	1.20	1.65	2.50	1.30	.40	.35	.50	.65	.70
11	1.50	1.00	1.25	1.25	1.65	2.50	1.20	.40	.30	.50	.65	.65
12	.95	1.25	1.25	1.30	1.90	2.70	1.20	.40	.30	.50	.65	.65
13	1.00	1.50	1.35	1.35	1.95	2.70	1.25	.40	.30	.50	.65	.65
14	1.00	2.20	1.25	1.40	2.10	2.80	1.15	.40	.30	.50	.65	.65
15	1.00	2.55	1.30	1.50	2.15	2.75	1.10	.40	.30	.55	.65	.65

Daily gage height, in feet, of South Fork of Humboldt River at Masons Ranch, Nevada, for 1898—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
16	1.05	2.75	1.00	1.60	2.20	2.80	1.05	.40	.30	.55	.65	.65
17	1.10	2.25	1.10	1.70	2.25	2.80	1.00	.35	.30	.55	.65	.65
18	1.05	2.30	1.30	1.70	2.35	2.90	.90	.35	.35	.55	.65	.65
19	1.10	2.30	1.30	1.70	2.75	2.80	.90	.35	.35	.55	.65	.65
20	1.10	2.10	1.30	1.70	2.70	2.70	.90	.35	.40	.55	.65	.65
21	1.05	2.55	1.30	1.90	2.45	2.50	.85	.30	.40	.55	.60	.65
22	1.10	2.30	1.20	1.85	2.40	2.40	.85	.30	.40	.60	.60	.65
23	1.05	1.55	1.25	1.75	2.30	2.40	.80	.30	.40	.60	.60	.65
24	1.00	1.60	1.20	1.70	2.20	2.35	.75	.30	.40	.60	.60	.65
25	1.00	1.50	1.30	1.75	2.10	2.30	.75	.30	.40	.60	.60	.70
26	1.05	1.45	1.30	1.90	2.10	2.30	.65	.30	.40	.60	.60	.80
27	1.10	1.55	1.30	2.10	2.10	2.20	.65	.30	.40	.60	.60	.80
28	1.10	1.60	1.30	2.10	2.50	2.00	.60	.30	.40	.65	.60	.90
29	1.20	.....	1.30	2.10	2.85	2.00	.60	.30	.40	.65	.80	.90
30	1.30	.....	1.30	2.00	2.65	1.85	.55	.30	.40	.65	.90	1.00
31	1.40	.....	1.30	.....	2.55	.....	.50	.30	.....	.65	.....	1.00

Daily gage height, in feet, of Bear River at Soda Springs, Idaho, for 1898.

Day.	May.	June.	July.	Day.	May.	June.	July.	Day.	May.	June.	July.
1	.....	7.10	6.30	12	.....	6.60	.....	23	6.80	6.60	.....
2	.....	7.10	.....	13	.....	.....	.....	24	6.85	6.60	.....
3	.....	7.10	.....	14	.....	6.55	.....	25	6.90	6.60	.....
4	.....	7.10	.....	15	.....	6.50	.....	26	6.90	6.60	.....
5	.....	7.10	.....	16	.....	6.60	.....	27	6.90	6.50	.....
6	.....	7.00	.....	17	.....	6.60	.....	28	7.20	6.40	.....
7	.....	7.00	.....	18	.....	6.60	.....	29	7.10	6.40	.....
8	.....	6.90	.....	19	.....	6.60	.....	30	7.10	6.40	.....
9	.....	6.90	.....	20	.....	6.60	.....	31	7.10	.....	.....
10	.....	6.90	.....	21	.....	6.60	.....				
11	.....	6.90	.....	22	6.90	6.60	.....				

Discontinued July 1.

Daily gage height in feet, of Bear River at Battle Creek, Idaho, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.90	2.00	1.85	1.90	3.70	3.70	2.70	1.50	1.40	1.40	1.60	1.60
2	1.90	2.00	1.85	1.90	3.70	3.70	2.60	1.50	1.40	1.40	1.60	1.60
3	1.90	2.00	1.90	2.00	3.60	3.60	2.60	1.50	1.40	1.40	1.60	1.30
4	1.90	2.00	1.90	2.00	3.60	3.60	2.50	1.50	1.40	1.40	1.60	1.60
5	1.90	2.05	1.95	2.10	3.60	3.60	2.50	1.40	1.40	1.40	1.60	1.60
6	1.90	1.90	1.95	2.20	3.60	3.50	2.50	1.40	1.40	1.40	1.60	1.60
7	1.90	1.90	1.95	2.40	3.55	3.50	2.40	1.40	1.40	1.40	1.60	1.60
8	1.90	1.90	1.95	2.50	3.50	3.50	2.30	1.40	1.40	1.40	1.60	1.60
9	1.90	1.90	2.00	2.70	3.50	3.40	2.30	1.40	1.40	1.40	1.60	1.60
10	1.90	1.90	2.00	3.00	3.50	3.40	2.20	1.40	1.40	1.40	1.60	1.60
11	1.90	1.90	1.90	3.20	3.45	3.40	2.20	1.40	1.40	1.40	1.60	1.60
12	2.00	1.90	1.90	3.20	3.40	3.40	2.20	1.40	1.40	1.40	1.60	1.60
13	2.10	1.80	1.90	3.20	3.40	3.30	2.10	1.40	1.40	1.40	1.60	1.60
14	2.10	1.70	1.90	3.30	3.35	3.30	2.10	1.40	1.40	1.50	1.60	1.60
15	2.10	1.70	1.90	3.30	3.30	3.30	2.10	1.40	1.40	1.50	1.60	1.60
16	2.10	1.60	1.90	3.40	3.30	3.20	2.10	1.40	1.40	1.50	1.60	1.60
17	2.10	1.60	1.90	3.40	3.35	3.00	2.00	1.40	1.40	1.50	1.60	1.60
18	2.10	1.60	1.90	3.50	3.40	3.00	2.00	1.40	1.40	1.50	1.60	1.60
19	2.10	1.60	1.90	3.60	3.50	3.00	1.90	1.40	1.40	1.50	1.60	1.60
20	2.10	1.60	1.90	3.70	3.50	3.00	1.80	1.40	1.40	1.50	1.60	1.60
21	2.10	1.60	1.90	3.70	3.50	3.00	1.80	1.40	1.40	1.50	1.60	1.60
22	2.10	1.60	1.90	3.80	3.50	3.00	1.80	1.40	1.40	1.50	1.60	1.60
23	2.00	1.60	1.60	3.90	3.40	2.90	1.80	1.40	1.40	1.50	1.60	1.60
24	2.00	1.60	1.60	3.90	3.40	2.90	1.70	1.40	1.40	1.50	1.60	1.60
25	2.00	1.60	1.80	3.90	3.30	2.90	1.70	1.40	1.40	1.50	1.60	1.60
26	2.00	1.70	1.80	3.85	3.40	2.90	1.70	1.40	1.40	1.50	1.60	1.60
27	2.00	1.70	1.70	3.80	3.50	2.90	1.70	1.40	1.40	1.60	1.60	1.60
28	2.00	1.80	1.70	3.80	3.60	2.80	1.60	1.40	1.40	1.60	1.60	1.60
29	2.00	.....	1.80	3.70	3.70	2.70	1.60	1.40	1.40	1.60	1.60	1.60
30	2.00	.....	1.80	3.70	3.70	2.70	1.50	1.40	1.40	1.60	1.60	1.60
31	2.00	.....	1.90	.....	3.70	.....	1.50	1.40	.....	1.60	.....	1.60

ght, in feet, of Logan River at Logan, Utah, for 1898.

Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
2.50	2.50	3.40	3.75	3.35	2.85	2.75	2.60	2.60	2.55
2.50	2.50	3.30	3.80	3.30	2.85	2.75	2.60	2.60	2.55
2.50	2.50	3.30	3.80	3.30	2.85	2.75	2.65	2.60	2.50
2.50	2.50	3.25	3.80	3.25	2.85	2.70	2.65	2.60	2.50
2.50	2.45	3.25	3.70	3.20	2.80	2.70	2.65	2.60	2.45
2.50	2.50	3.25	3.70	3.20	2.80	2.70	2.65	2.60	2.45
2.50	2.55	3.35	3.65	3.15	2.80	2.70	2.65	2.60	2.40
2.50	2.55	3.35	3.70	3.15	2.80	2.70	2.65	2.60	2.30
2.55	2.55	3.35	3.75	3.10	2.80	2.65	2.65	2.60	2.30
2.50	2.65	3.40	3.75	3.10	2.75	2.65	2.65	2.60	2.40
2.40	2.75	3.70	3.75	3.00	2.75	2.65	2.65	2.60	2.30
2.45	2.85	3.65	3.75	3.05	2.75	2.65	2.65	2.60	2.35
2.45	2.85	3.65	3.75	3.05	2.75	2.65	2.60	2.55	2.40
2.50	2.95	3.65	3.75	3.05	2.75	2.65	2.60	2.50	2.40
2.50	3.00	3.65	3.75	3.05	2.90	2.65	2.60	2.55	2.45
2.45	3.15	3.65	3.75	3.00	2.80	2.65	2.60	2.55	2.45
2.45	3.25	3.65	3.75	3.00	2.75	2.65	2.60	2.55	2.45
2.45	3.20	3.65	3.75	3.00	2.75	2.65	2.60	2.55	2.45
2.50	3.15	3.65	3.75	3.00	2.75	2.65	2.60	2.55	2.45
2.50	3.25	3.60	3.70	3.00	2.75	2.65	2.60	2.55	2.45
2.50	3.45	3.55	3.65	2.95	2.90	2.60	2.60	2.55	2.45
2.50	3.30	3.60	3.60	2.95	2.90	2.60	2.60	2.55	2.40
2.45	3.25	3.60	3.70	2.95	2.90	2.60	2.60	2.55	2.35
2.45	3.25	3.70	3.65	2.95	2.90	2.60	2.60	2.55	2.35
2.45	3.30	3.70	3.60	2.90	2.85	2.60	2.60	2.55	2.40
2.45	3.50	3.65	3.55	2.90	2.80	2.60	2.60	2.55	2.50
2.45	3.55	3.65	3.50	2.85	2.80	2.60	2.60	2.50	2.55
2.45	3.50	3.85	3.45	2.85	2.75	2.60	2.60	2.55	2.55
2.45	3.45	3.75	3.40	2.80	2.75	2.60	2.60	2.60	2.55
2.50	3.40	3.75	3.40	2.80	2.75	2.60	2.60	2.60	2.55
2.60	.....	3.75	.....	2.85	2.75	.....	2.60	.....	2.55

ht, in feet, of Bear River at Collinston, Utah, for 1898.

Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
2.45	2.35	4.40	4.75	2.55	1.30	1.10	1.30	1.70	1.90
2.75	2.40	4.35	4.80	2.50	1.30	1.10	1.40	1.70	1.90
2.75	2.40	4.30	4.80	2.40	1.25	1.10	1.50	1.70	1.90
2.80	2.40	4.30	4.80	2.30	1.20	1.10	1.50	1.70	1.60
2.80	2.55	4.20	4.80	2.25	1.20	1.20	1.60	1.70	1.40
2.80	2.60	4.20	4.75	2.20	1.15	1.20	1.60	1.70	1.40
2.65	2.60	4.20	4.70	2.15	1.10	1.10	1.60	1.70	1.40
2.60	2.65	4.20	4.60	2.10	1.10	1.10	1.60	1.70	1.40
2.60	2.75	4.10	4.55	2.00	1.10	1.10	1.60	1.70	1.40
2.60	2.90	4.05	4.40	2.00	1.10	1.10	1.60	1.70	1.70
2.40	3.30	4.00	4.10	2.00	1.10	1.10	1.60	1.70	1.20
2.30	3.60	3.90	4.00	1.95	1.10	1.10	1.60	1.70	1.20
2.30	3.85	3.90	3.90	1.85	1.10	1.10	1.60	1.70	1.20
2.30	4.05	3.95	3.70	1.80	1.10	1.20	1.60	1.70	1.20
2.30	4.15	3.90	3.55	1.70	1.10	1.20	1.60	1.70	1.20
2.20	4.20	3.90	3.40	1.70	1.10	1.20	1.60	1.70	1.50
2.30	4.20	3.95	3.30	1.80	1.10	1.20	1.60	1.70	1.50
2.30	4.30	4.30	3.20	1.75	1.10	1.20	1.60	1.80	1.50
2.30	4.30	4.30	3.20	1.70	1.10	1.20	1.60	1.80	1.50
2.30	4.35	4.40	3.20	1.60	1.10	1.20	1.70	1.90	1.50
2.30	4.40	4.50	3.20	1.60	1.10	1.20	1.70	1.90	1.50
2.10	4.45	4.50	3.20	1.55	1.10	1.20	1.70	1.90	1.50
2.10	4.55	4.50	3.15	1.50	1.10	1.20	1.70	1.70	1.40
2.10	4.60	4.50	3.10	1.50	1.10	1.30	1.70	1.70	1.40
2.15	4.60	4.60	3.10	1.45	1.10	1.30	1.70	1.70	1.40
2.20	4.60	4.60	3.10	1.40	1.10	1.30	1.70	1.70	1.40
2.10	4.60	4.60	3.10	1.30	1.10	1.30	1.70	1.60	1.40
2.15	4.50	4.60	3.00	1.30	1.10	1.30	1.70	1.50	1.40
2.20	4.50	4.60	2.85	1.30	1.10	1.30	1.70	1.70	1.30
2.25	4.50	4.65	2.70	1.30	1.10	1.30	1.70	1.80	1.30
2.30	.....	4.70	.....	1.30	1.10	.....	1.70	.....	1.30

INTERIOR BASIN DR.

Adjusted gage height, in feet, of Ogden River

Jan. Feb. Mar. Apr. May. June Ju

Discharge gage height, in feet, of Weber

Jan. Feb. Mar. Apr. May. J

gage height, in feet, of [illegible]

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	[illegible]	[illegible]	[illegible]
1.05	2.75	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.10	2.85	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.05	2.80	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.10	2.40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.10	2.10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.05	2.55	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.10	2.30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.05	1.55	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.00	1.60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.00	1.50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.05	1.45	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.10	1.55	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.10	1.60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.30	.....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.30	.....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.40	.....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

gage height, in feet, of [illegible]

May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
.....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.....	[illegible]	.....

Daily gage height, in feet, of Provo River at Provo, Utah, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.30	4.20	4.40	4.40	5.20	5.40	4.20	3.80	3.80	3.80	4.10	4.20
2	4.30	4.20	4.40	4.40	5.20	5.50	4.20	3.80	3.80	3.80	4.10	4.20
3	4.30	4.20	4.40	4.40	5.10	5.50	4.00	3.80	3.80	3.80	4.10	4.20
4	4.30	4.20	4.40	4.40	5.10	5.50	4.00	3.80	3.80	3.80	4.10	4.20
5	4.30	4.20	4.40	4.40	5.00	5.30	4.00	3.80	3.80	3.80	4.10	4.20
6	4.30	4.20	4.40	4.40	5.00	5.20	4.00	3.80	3.80	3.80	4.20	4.20
7	4.30	4.20	4.40	4.40	5.00	5.20	4.00	3.80	3.80	3.80	4.20	4.20
8	4.30	4.20	4.40	4.40	5.10	5.20	4.00	3.80	3.80	3.80	4.20	4.20
9	4.10	4.20	4.40	4.40	5.10	5.20	4.00	3.80	3.80	3.80	4.20	4.20
10	4.10	4.20	4.40	4.40	5.10	5.00	4.00	3.80	3.80	3.80	4.20	4.20
11	4.10	4.20	4.40	4.50	5.10	5.00	4.00	3.80	3.80	3.80	4.20	4.20
12	4.10	4.20	4.40	4.50	5.20	5.10	4.00	3.80	3.80	3.80	4.20	4.20
13	4.10	4.20	4.40	4.60	5.20	5.20	4.00	3.80	3.80	3.80	4.20	4.20
14	4.10	4.20	4.40	4.60	5.20	5.40	4.00	3.80	3.80	3.80	4.20	4.20
15	4.10	4.20	4.40	4.60	5.20	5.40	4.00	3.80	3.80	3.80	4.20	4.20
16	4.10	4.20	4.40	4.70	5.20	5.40	4.00	3.80	3.80	4.10	4.20	4.20
17	4.10	4.20	4.40	4.60	5.20	5.10	3.90	3.80	3.80	4.10	4.20	4.20
18	4.10	4.20	4.40	4.70	5.20	5.00	3.90	3.80	3.80	4.10	4.20	4.10
19	4.10	4.20	4.40	4.80	5.20	4.70	3.90	3.80	3.80	4.10	4.20	4.10
20	4.10	4.20	4.40	4.90	5.20	4.70	3.90	3.80	3.80	4.10	4.20	4.10
21	4.10	4.20	4.40	4.60	5.20	4.70	3.90	3.80	3.80	4.10	4.20	4.10
22	4.10	4.20	4.40	4.60	5.10	4.90	3.90	3.70	3.80	4.10	4.20	4.10
23	4.20	4.30	4.40	4.70	5.00	4.80	3.90	3.70	3.80	4.10	4.20	4.10
24	4.20	4.40	4.40	4.80	5.40	4.70	3.80	3.70	3.80	4.10	4.20	4.10
25	4.20	4.40	4.40	4.90	5.40	4.70	3.80	3.70	3.80	4.10	4.20	4.20
26	4.20	4.40	4.40	5.10	5.30	4.60	3.80	3.70	3.80	4.10	4.20	4.20
27	4.20	4.40	4.40	5.10	5.20	4.60	3.80	3.70	3.80	4.10	4.20	4.20
28	4.20	4.40	4.40	5.10	5.20	4.40	3.80	3.70	3.80	4.10	4.20	4.20
29	4.20	.....	4.40	5.20	5.30	4.40	3.80	3.80	3.80	4.10	4.20	4.20
30	4.20	.....	4.40	5.20	5.30	4.20	3.80	3.80	3.80	4.10	4.20	4.20
31	4.20	.....	4.40	.....	5.40	.....	3.80	3.80	.....	4.10	.....	4.20

Daily gage height, in feet, of Utah Lake at Geneva, Utah, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	1.40	1.40	.....	.....	2.00	.....	1.00	.....	.....	0.75	.....
2	.....	.....	.....	.....	1.50	.....	1.65	.....	.....	.....	.....	.....
3	1.00	1.40	1.45	.....	.....	.....	.....	.....	0.20	0.65	.75	.....
4	.....	.....	.....	1.55	1.70	2.00	1.60	.90	.....	.....	.....	.....
5	1.05	1.45	1.50	.....	.....	.....	.....	.....	.25	.....	.75	0.55
6	.....	.....	.....	1.50	.....	2.10	.....	.90	.....	.65	.....	.....
7	.....	1.40	1.50	.....	1.65	.....	1.60	.....	.25	.....	.75	.55
8	1.10	.....	.....	.....	.....	2.00	.....	.90	.....	.65	.....	.....
9	.....	1.35	1.50	1.50	1.70	.....	1.55	.....	.....	.....	.....	.....
10	1.10	.....	.....	.....	.....	.....	.....	.80	.40	.65	.75	.55
11	.....	.....	.....	1.45	1.70	1.95	1.55	.....	.....	.....	.....	.....
12	1.10	1.30	1.50	.....	.....	.....	.....	.....	.45	.70	.70	.....
13	.....	.....	.....	.....	.....	2.00	.....	.75	.....	.....	.....	.....
14	.....	1.30	1.50	1.45	1.70	.....	1.55	.....	.....	.....	.70	.....
15	1.15	.....	.....	.....	.....	.....	.....	.80	.40	.70	.....	.....
16	.....	.....	1.50	1.45	1.70	2.00	1.40	.....	.....	.....	.....	.55
17	1.20	1.30	.....	.....	.....	.....	.....	.....	.45	.....	.75	.55
18	.....	.....	.....	1.40	1.75	1.90	1.60	.....	.....	.70	.....	.....
19	.....	1.30	1.55	.....	.....	.....	.....	.....	.45	.....	.80	.50
20	1.25	.....	.....	.....	.....	1.90	.....	.....	.....	.65	.....	.....
21	.....	1.35	1.55	1.40	1.80	.....	1.25	.....	.....	.....	.....	.....
22	1.30	.....	.....	.....	.....	1.90	.....	.....	.50	.70	.....	.....
23	.....	1.35	1.55	1.40	1.90	.....	1.20	.....	.....	.....	.....	.....
24	1.30	.....	.....	.....	.....	.....	.....	.....	.55	.75	.70	.45
25	.....	.....	.....	1.40	.....	1.85	1.15	.50	.....	.....	.....	.....
26	1.35	1.40	1.55	.....	1.95	.....	.....	.50	.60	.....	.75	.40
27	.....	.....	.....	1.40	.....	1.80	.....	.50	.....	.70	.....	.....
28	.....	.....	1.55	.....	2.00	.....	1.10	.....	.....	.....	.65	.....
29	1.35	.....	.....	.....	.....	1.80	.....	.....	.65	.75	.....	.....
30	.....	.....	.....	1.40	2.00	.....	1.10	.....	.65	.....	.60	.....
31	.....	.....	1.55	.....	.....	.....	.....	.....	.....	.....	.....	.40

List of discharge measurements, 1898.

Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
			Feet.	*Sec.-feet.*
North Fork of Humboldt River.	Peko, Nev	L. H. Taylor	2.65	43
do	do	do	3.20	129
do	do	do	2.90	71
do	do	do	1.80	6
do	do	do	1.45	.3
Humboldt River	Elko, Nev	do	4.03	423
do	do	do	2.80	140
do	do	do	3.40	271
do	do	do	3.60	316
do	do	do	2.10	44
do	do	do	1.70	1
do	Golconda, Nev	do	4.20	436
do	do	do	2.90	239
do	do	do	2.40	162
do	do	do	.95	24
do	do	do	3.70	341
do	do	do	1.50	70
do	do	do	0.00	.2
do	Oreana, Nev	do	3.30	324
do	do	do	2.85	193
do	do	do	1.50	43
do	do	do	1.25	21
do	do	do	1.41	38
South Fork of Humboldt River.	Masons Ranch, Nev.	do	1.55	159
do	do	do	2.05	275
do	do	do	2.30	313
do	do	do	.85	52
do	do	do	.35	.7
Bear River	Soda Springs, Idaho.	F. J. Mills	6.60	2,049
do	do	C. C. Babb	5.00	290
do	do	F. S. Shirley	5.15	519
do	Battle Creek, Idaho.	J. S. Baker	3.65	3,016
do	do	do	3.40	2,594
do	do	do	2.98	1,997
do	do	do	1.45	592
do	do	do	1.38	508
do	do	do	1.38	539
do	do	do	1.67	673
Logan River	Logan, Utah	do	2.75	229
do	do	do	2.88	281
do	do	do	3.35	474
do	do	do	3.35	475
do	do	do	3.65	652
do	do	do	3.75	690
do	do	do	3.75	723
do	do	do	3.72	663
do	do	do	2.82	283
do	do	do	2.85	204
do	do	do	2.85	210
do	do	do	2.57	155
Bear River	Collinston, Utah	S. Fortier	4.18	4,797
do	do	J. L. Rhead	3.27	3,419
do	do	do	3.04	3,136
do	do	J. S. Baker	3.06	2,724
do	do	J. L. Rhead	1.20	809
do	do	do	1.13	732
do	do	do	1.35	852
Ogden River	Ogden, Utah	J. S. Baker	2.11	134
do	do	do	1.45	27
do	do	do	1.45	36
Weber River	Uinta, Utah	do	2.90	1,327
do	do	do	1.05	104
do	do	do	1.05	104
do	do	do	1.10	125
Provo River	Provo, Utah	W. B. Dougall	4.85	704
do	do	do	5.20	938
do	do	do	3.85	192

Rating tables.

Elko.		Peko.		Golconda.		Oreana.		Masons Ranch.		Soda S
Gage height.	Dis-charge.	Gage height.	Dis-charge.	Gage height.	Dis-charge.	Gage height.	Dis-charge.	Gage height.	Dis-charge.	Gage height
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*
1.6	0.6	1.4	0.1	0.0	0.2	1.0	13	0.3	0.0	5.0
1.7	1.0	1.5	1.0	.1	.4	1.1	17	.4	6.0	5.1
1.8	6.0	1.6	2.0	.2	1.0	1.2	22	.5	14.0	5.2
1.9	15.0	1.7	4.0	.3	2.0	1.3	28	.6	24.0	5.3
2.0	24.0	1.8	6.0	.4	4.0	1.4	34	.7	34.0	5.4
2.1	34.0	1.9	8.0	.5	6.0	1.5	41	.8	45.0	5.5
2.2	45.0	2.0	11.0	.6	9.0	1.6	48	.9	57.0	5.6
2.3	57.0	2.1	14.0	.7	13.0	1.7	56	1.0	70.0	5.7
2.4	71.0	2.2	18.0	.8	17.0	1.8	64	1.1	84.0	5.8
2.5	86.0	2.3	23.0	.9	22.0	1.9	73	1.2	99.0	5.9
2.6	102.0	2.4	28.0	1.0	27.0	2.0	82	1.3	115.0	6.0
2.7	119.0	2.5	34.0	1.2	40.0	2.1	92	1.4	132.0	6.1
2.8	137.0	2.6	41.0	1.4	55.0	2.2	103	1.5	150.0	6.2
2.9	156.0	2.7	50.0	1.6	73.0	2.3	115	1.6	169.0	6.3
3.0	177.0	2.8	60.0	1.8	93.0	2.4	128	1.7	189.0	6.4
3.1	199.0	2.9	72.0	2.0	115.0	2.5	142	1.8	210.0	6.5
3.2	222.0	3.0	86.0	2.2	138.0	2.6	157	1.9	231.0	6.6
3.3	245.0	3.1	102.0	2.4	163.0	2.7	174	2.0	253.0	6.7
3.4	269.0	3.2	120.0	2.6	190.0	2.8	192	2.1	276.0	6.8
3.5	294.0	3.3	141.0	2.8	218.0	2.9	211	2.2	290.0	6.9
3.6	319.0	3.4	164.0	3.0	246.0	3.0	231	2.3	323.0	7.0
3.7	344.0	3.5	189.0	3.2	276.0	3.2	274	2.4	347.0	7.1
3.8	370.0	3.6	215.0	3.4	306.0	3.4	321	2.5	371.0	7.2
3.9	396.0	3.7	243.0	3.6	336.0	3.6	370	2.6	396.0	7.3
4.0	423.0	3.8	272.0	3.8	367.0	3.8	421	2.7	421.0	7.4
4.1	450.0	3.9	302.0	4.0	400.0	4.0	474	2.8	447.0	7.5
4.2	478.0	4.0	333.0	4.2	434.0	4.2	528	2.9	473.0	.....
4.3	506.0	.....	.....	4.4	468.0	4.4	584	3.0	499.0	.....
4.4	535.0	.....	.....	4.6	502.0	4.6	642	.....	.....	.....
4.5	565.0	.....	.....	.....	.....	.....	.....	.....	.....	.....

Battle Creek.		Logan.		Collinston.		Ogden.		Uinta.		Pr
Gage height.	Dis-charge.	Gage height.	Dis-charge.	Gage height.	Dis-charge.	Gage height.	Dis-charge.	Gage height.	Dis-charge.	Gage height
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet*
1.0	344	2.3	108	1.0	660	1.0	23	1.0	95	3.6
1.1	386	2.4	125	1.2	775	1.1	25	1.1	125	3.7
1.2	432	2.5	142	1.4	920	1.2	26	1.2	165	3.8
1.3	482	2.6	167	1.6	1,085	1.3	28	1.3	210	3.9
1.4	535	2.7	197	1.8	1,275	1.4	30	1.4	260	4.0
1.5	598	2.8	229	2.0	1,490	1.5	32	1.5	310	4.1
1.6	660	2.9	264	2.2	1,740	1.6	34	1.6	360	4.2
1.7	725	3.0	305	2.4	2,010	1.7	36	1.7	415	4.3
1.8	790	3.1	345	2.6	2,280	1.8	39	1.8	475	4.4
1.9	870	3.2	392	2.8	2,555	1.9	41	1.9	545	4.5
2.0	950	3.3	445	3.0	2,840	2.0	44	2.0	620	4.6
2.2	1,125	3.4	500	3.2	3,110	2.1	48	2.2	770	4.7
2.4	1,312	3.5	554	3.4	3,385	2.2	52	2.4	920	4.8
2.6	1,514	3.6	609	3.6	3,660	2.3	56	2.6	1,080	4.9
2.8	1,757	3.7	670	3.8	3,935	2.4	61	2.8	1,240	5.0
3.0	2,020	3.8	740	4.0	4,200	2.5	67	3.0	1,410	5.1
3.2	2,312	3.9	815	4.2	4,475	2.6	73	3.2	1,580	5.2
3.4	2,625	4.0	895	4.4	4,760	2.7	81	3.4	1,750	5.3
3.6	2,945	4.1	986	4.6	5,025	2.8	90	3.6	1,925	5.4
3.8	3,306	4.2	1,084	4.8	5,315	2.9	102	3.8	2,118	5.5
4.0	3,660	4.3	1,194	5.0	5,590	3.0	116	4.0	2,326	5.6
4.2	4,025	4.4	1,304	5.2	5,875	3.1	134	4.2	2,534	5.7
4.4	4,417	4.5	1,425	5.4	6,160	3.2	157	4.4	2,742	5.8
4.6	4,810	4.6	1,555	5.6	6,440	3.3	187	4.6	2,950	5.9
4.8	5,212	4.7	1,685	5.8	6,725	3.4	220	4.8	3,158	6.0
5.0	5,620	4.8	1,864	6.0	7,010	3.5	253	5.0	3,366	6.1
5.2	6,025	4.9	2,034	6.5	7,710	3.6	286	5.5	3,886	6.2
5.4	6,440	5.0	2,210	7.0	8,445	3.7	319	6.0	4,406	6.3
5.6	6,860	.....	.....	.....	.....	3.8	352	6.5	4,926	.....
.....	.....	.....	.....	.....	.....	3.9	385	7.0	5,446	.....

COLUMBIA RIVER DRAINAGE.

DESCRIPTION OF RIVER STATIONS.

Pocatello station on Portneuf River.—Described on page 164 of Paper No. 16. Discharge measurements for 1898 made by F. J. Mills and Frank S. Shirley.

Montgomery station on Snake River.—Described on page 165 of Paper No. 16; results for 1897 given on pages 444–448 of the Nineteenth Annual Report, Part IV.

Toponis station on Malad and Little Wood rivers.—Described on page 165 of Paper No. 16; results for 1897 given on pages 448–449 of the Nineteenth Annual Report, Part IV. The observer was Willie Hickman. The bridge over the Malad or Big Wood River has been moved downstream one-half mile.

Grandview station on Bruneau River.—Described on page 167 of Paper No. 16; results for 1897 given on pages 450–451 of the Nineteenth Annual Report, Part IV. Data furnished by Andrew J. Wiley.

Boise station on Boise River.—Described on page 168 of Paper No. 16; results for 1897 given on pages 451–454 of the Nineteenth Annual Report, Part IV.

Weiser station on Weiser River.—Described on page 171 of Paper No. 16; results for 1897 given on pages 456–457 of the Nineteenth Annual Report, Part IV. Gage reset and bolted to a rock, August 22, by C. C. Babb and F. S. Shirley.

Hooper station on Palouse River.—Described on page 172 of Paper No. 16; results for 1897 given on pages 458–459 of the Ninteenth Annual Report, Part IV. Discharge measurements for 1898 were made by Sydney Arnold.

Bonner station on Blackfoot River.—This station is 6 miles east of Missoula and one-half mile west of Bonner, on the wagon bridge across Blackfoot River. It was established by Mr. Cyrus C. Babb, July 7, 1898. The observer is John McCormick, a ranchman, living near the station. Observations are made at about 7 a. m. and 6 p. m. A wire gage is used, the length being 22.90 feet, and the distance from the zero mark on the gage to the farther edge of the pulley is 2 feet. The bench mark is that established by the topographers about 300 yards above on the Northern Pacific Railway bridge. This bench mark has not yet been connected with the river gage. The initial point for soundings is the left end of the plank rail on the lower side of the bridge, about 15 feet from the water. The channel is nearly straight, the right bank low, and the left bank high and rocky. The bed of the stream shifts slightly. The water empties into Missoula River about 500 yards below the bridge.

Blackfoot River receives the water from the portions of Missoula and Deer Lodge counties between the watersheds of the Mission Range and the main range of the Rocky Mountains. The Clearwater Lakes near

the head waters serve as reservoirs, giving the stream a relatively constant flow. The economic importance of the river is great on account of its rapid fall, the volume of water discharged, and its purity. The principal industrial applications are found near the mouth of the river, where power can be obtained and water used upon adjacent lands for irrigation. The measurements, therefore, at Bonner are particularly valuable. The conditions are favorable for accurate measurement, except for the fact that the height of water is influenced by a dam of the Big Blackfoot Milling Company, located about 1,000 yards above, furnishing water for mills and electric-power stations. The opening and closing of the flood gates of the dam causes abrupt changes in the flow of the stream.

Missoula station on Bitterroot River.—This station is on the Buckhouse wagon bridge, on the main road, 6 miles southwest of Missoula. It was established by Mr. Cyrus C. Babb, and observations were begun on July 6, 1898. The observer is Joe Buckhouse, a farmer living one-half mile from the bridge. Observations are made at 7 a. m. A wire gage is used, with a 5-pound sash weight. The length of the gage wire is 22.83 feet, and the pulley distance—that is, the distance from the zero of the gage to the outside edge of the pulley—is 0.50 feet. A bench mark has been established by the topographers. This consists of a nail in the base of the Northern Pacific Railway sign crossing, 120 feet from the west end of the bridge. This nail is at an elevation of 3,127.6 feet above sea level. It is about 20 feet above the floor of the bridge. The initial point for soundings is directly over the inside edge of the cylindrical casement of the abutment of the bridge, on the upper side at the left hand end. The channel is nearly straight; the right bank low and liable to overflow, the left bank high and rocky. The bed of the stream is of gravel, in which an old pier of a former bridge remains near the center of the stream, causing annoyance in measurements when the water is high. The results obtained at the Buckhouse Bridge, which is near the mouth of the river, are of value mainly in giving the total discharge of the stream. On account of the slight fall water can not be diverted for irrigation for a distance of 25 miles or more above this locality. At a point 10 miles above the station the river is 4 feet lower than the valley around Missoula. The total fall from Hamilton to Missoula, a distance of 48 miles, is about 350 feet. The measurements have a high degree of accuracy since the stream is deep, the current relatively slow, and the fluctuations in height are gradual.

Missoula station on Missoula River.—This station is located at the Higgins Avenue Bridge in Missoula, across the river of that name. It was originally established by Mr. Cyrus C. Babb, and observations were begun on July 10, 1898. The observer is E. S. Newton, a carpenter, whose workshop is on the bank of the river. Observations are made at 7 a. m. and 6 p. m. The gage consists of two rods, one fastened to a pile, the other to planking on one of the piers at the north end

the bridge. The elevation of the zero is 3,156 feet above sea level, verified by the topographers of the United States Geological Sur-y. Bench mark No. 1 consists of a nail in the top of a 10-inch by inch post of the old bridge, 2.5 feet above ground and 36 feet north-stward of the rod, its elevation being 3,170.25 feet above sea level, 14.25 feet above the zero of the rod. The second bench mark con-ts of a nail in the piling of the bridge to which the gage rod is tened; it is opposite the 8-foot mark. On August 10 the gage on pile at the north end of the bridge was out of water, and the sec-d rod was nailed to the pier of the bridge, about 20 feet from the st. All graduations on the first rod and all gage-height readings ve been changed to conform to the second rod.

Soundings and discharge measurements are taken from the railroad idge, about a mile below. The channel is nearly straight, the banks gh, and the bed rocky. During high water the left bank is flooded some distance above the bridge, and a second stream crosses the rs some 400 feet south of the main channel of the stream. The itial point for soundings is on the right end of the bridge at the edge the abutment.

Missoula River is one of the most important rivers west of the cky Mountains. Its drainage area, including that of Blackfoot iver, is 5,960 square miles. In its course to the Columbia the stream ars various names, being locally known as the Hellgate, the Mis-ula, and finally Clarkes Fork of the Columbia. Where measured at issoula the flow includes that of the Hellgate and Blackfoot rivers. here is a large extent of arable land along the river at and below issoula to which water may be brought from this stream. The pid fall will make the river valuable as a source of power wherever itable dams can be built. The slimes and tailings from the ore ncentrators at Butte and Anaconda render the water turbid and nfit for drinking.

It is proposed to construct a dam across the river 2 miles above issoula for the diversion of water into a large canal covering por-ons of the Missoula and Grass valleys, within which are thousands acres of nearly level land at present unproductive from lack of ater. By the construction of such a dam sufficient power can obably be obtained to generate electricity for local needs. Meas-ements made at Missoula give fairly accurate results and are of nsiderable importance in discussing projects of this nature.

Lakeside station on Lake Chelan.—A gage on this lake was estab-hed by Capt. Charles Johnson at the base of the rock pier on the lake ore north of his house and about one-half mile from the steamboat nding at Lakeside. This consists of a timber 2 inches square and 8 et high, marked to feet and tenths. Observations were maintained om September 1 to October 15, 1897, at which time they were dis-ntinued until January 1, 1898. This gage is located about 400 feet rth*west from the permanent* bench mark established by Mr. William

T. Griswold in 1897, consisting of the usual iron post with brass cap, the elevation stamped on the top being 1,121 feet above sea level. The iron post is on the west line of East Center street in the town of Lakeside. In the readings given on page 164 the figures 1,100 should be added to give the elevation above tide.

Capt. Charles Johnson, of Lakeside, Washington, writes concerning Lake Chelan as follows:

This lake is fed by mountain streams which have their sources in the glaciers of the Cascade Mountains, furnishing the lake with water as pure as crystal. The Stehekin River, the main tributary of the lake, finds its source on the very summit of the Cascades in glaciers of great extent and magnificence. The foot of the lake is 3 miles from Columbia River, at an elevation of 360 feet above the river, into which the waters flow through Chelan River. From the foot the lake extends in a northwest direction, penetrating the Cascade Mountains almost to their center, affording a panorama of majestic scenery that is rarely found on the shores of any lake.

At the foot of the lake, and for 25 miles up, it is surrounded with low foothills and good soil, well adapted to farming and horticulture. From thence the mountains rise higher and higher, with almost perpendicular granite walls, until at the head of the lake the mountain peaks stand 8,000 to 10,000 feet above sea level. The lake has now four steamers plying its waters, supplying the many mining camps in the uplake region and affording accommodations to tourists and pleasure seekers. The lake is open to navigation for the whole year. This is due to the great depth of the lake and the mild temperature of the region. The average winter temperature is about 27° to 28° F.

North Yakima station on Naches River.—This station, originally established August 14, 1893, and abandoned in February, 1897, was reestablished on February 1, 1898; and the station at Selah, on the Yakima River, described in the Nineteenth Annual Report, Part IV, pages 477–479, 5 miles above the mouth of the Naches, was discontinued. The observer is Pat. Gallagher, section foreman. Since the reestablishment of the Naches station the river channel has been in a condition more favorable for meter observations than formerly. Discharge measurements are made from the lower side of the highway bridge. A new horizontal gage rod, with wire and weight, has been attached to the main span of the Northern Pacific Railway bridge at the mouth of the Naches, a few hundred feet downstream from the highway bridge. The length of the gage wire from index to foot of weight is 30.41 feet. The pulley distance is 5.844 feet. The elevation of top of pulley is 24.57 feet. The bench mark is the top of the north end of east sill of clearance posts, about 150 feet north of Northern Pacific Railway bridge. Elevation, 23.766 feet. On December 27, 1898, Mr. Arnold connected the highway bridge with this bench mark. The top of the northeast concrete pier was found to be at an elevation of 22.09 feet, and the top of the bridge post at the 150-foot mark, at an elevation of 26.76 feet. The distance from top of post to surface of water has been carefully measured at each discharge measurement, so that the exact river height at the highway bridge is known.

Union Gap station on Yakima River.—Described on page 175 of 'aper No. 16; results for 1897 given on pages 479–481 of the Nineeenth Annual Report, Part IV. The old bench mark having been bliterated, a new one has been set. It is the highest point of a large ock mound, 25 feet north of gage and 10 feet east of fence; elevaion, 17.52 above zero of gage rod.

Kiona station on Yakima River.—Described on page 176 of Paper Io. 17; results for 1897 given on pages 482–486 of the Nineteenth nnual Report, Part IV.

Spokane station on Spokane River.—Described on page 177 of Paper Io. 16; results for 1897 given on pages 487–489 of the Nineteenth nnual Report, Part IV.

Whitman station on Wallawalla River.—Described on page 179 of 'aper No. 16; results for 1898 given on pages 490–492 of the Nineeenth Annual Report, Part IV.

Gibbon station on Umatilla River.—Described on page 180 of Paper Io. 16; results for 1897 given on pages 493, 494 of the Nineteenth Annual Report, Part IV.

Moro station on Deschutes River.—Described on page 181 of Paper No. 16. A measurement was made in 1898 by Sydney Arnold. No ating table was constructed, for lack of sufficient data.

Tucker station on Hood River.—Described on page 181 of Paper No. 16; results for 1897 given on pages 498–500 of the Nineteenth Annual Report, Part IV.

TABLES OF DAILY GAGE HEIGHT.

Daily gage height, in feet, of Portneuf River at Pocatello, Idaho, for 1898.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	7.60	7.30	7.40	6.90	6.60	6.70	6.80	7.10	7.10
2	.....	7.60	7.20	7.50	7.00	6.60	6.65	6.80	7.10	7.10
3	.....	7.70	7.20	7.60	7.00	6.60	6.65	6.80	7.10	7.10
4	.....	7.80	7.20	7.60	6.10	6.60	6.65	6.80	7.10	7.20
5	.....	7.80	7.20	7.60	6.10	6.60	6.65	6.85	7.20	7.20
6	.....	7.80	7.20	7.60	6.10	6.60	6.60	6.85	7.20	7.20
7	.....	8.00	7.30	7.70	6.10	6.60	6.65	6.90	7.20	7.20
8	.....	8.00	7.30	7.90	6.10	6.70	6.70	6.90	7.20	7.20
9	.....	8.00	7.30	7.90	6.10	6.70	6.70	6.90	7.20	7.20
10	.....	8.00	7.30	7.90	6.10	6.70	6.65	6.90	7.10	7.20
11	.....	7.90	7.40	8.00	6.10	6.60	6.65	6.90	7.10	7.20
12	.....	7.80	7.40	7.10	6.20	6.70	6.70	6.90	7.10	7.30
13	.....	7.80	7.40	7.20	6.10	6.70	6.70	6.90	7.10	7.20
14	.....	7.70	7.40	7.30	7.10	6.70	6.70	6.90	7.10	7.10
15	.....	7.60	7.40	7.40	7.00	6.70	6.70	6.90	7.20	7.20
16	6.15	7.50	7.40	7.40	7.10	6.70	6.70	6.90	7.20	7.20
17	.....	7.40	7.40	7.40	6.10	6.60	6.70	6.90	7.20	7.20
18	.....	7.40	7.40	7.50	6.10	6.60	6.70	6.90	7.20	7.20
19	.....	7.40	7.30	7.40	6.20	6.70	6.65	6.90	7.30	7.30
20	.....	7.40	7.20	7.40	6.20	6.60	6.70	6.90	7.30	7.30
21	.....	7.40	7.20	7.30	6.30	6.70	6.70	6.90	7.20	7.40
22	.....	7.30	7.20	7.30	6.20	6.70	6.80	6.90	7.20	7.40
23	.....	7.20	7.30	7.20	6.20	6.65	6.80	7.00	7.20	7.50
24	.....	7.20	7.30	7.20	6.20	6.60	6.80	7.10	7.20	7.60
25	.....	7.20	7.30	7.20	6.20	6.60	6.80	7.20	7.20	7.60
26	.....	7.20	7.40	7.10	6.20	6.60	6.80	7.20	7.20	7.60
27	7.60	7.10	7.30	7.10	6.20	6.60	6.80	7.20	7.20	7.60
28	7.40	7.10	7.40	7.00	6.20	6.70	6.80	7.20	7.20	7.60
29	7.40	7.10	7.30	7.00	6.30	6.70	6.80	7.10	7.10	7.60
30	7.60	7.20	7.30	7.00	6.40	6.75	6.80	7.10	7.10	7.60
31	7.50	.....	7.40	.....	6.70	6.70	.....	7.20	.....	7.60

Daily gage height, in feet, of Snake River at Montgomery, Idaho, for 1898.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	2.90	6.85	8.20	6.30	2.80	1.90	2.20	2.80	2.90
2	.....	2.90	6.60	8.15	5.95	2.70	2.00	2.20	2.80	3.00
3	.....	2.90	6.30	7.75	5.70	2.60	2.10	2.30	2.80	3.00
4	.....	2.90	6.20	7.45	5.35	2.60	2.15	2.30	2.80	3.00
5	.....	2.90	6.25	7.25	5.25	2.55	2.20	2.30	2.80	2.90
6	.....	2.90	6.00	7.15	5.05	2.45	2.20	2.30	2.80	2.65
7	.....	2.90	5.70	6.95	4.90	2.35	2.20	2.30	2.80	3.80
8	.....	2.90	5.45	6.70	4.80	2.30	2.20	2.35	2.80	4.70
9	.....	2.90	5.40	6.35	4.75	2.20	2.20	2.40	2.80	4.45
10	.....	2.90	5.40	6.10	4.65	2.20	2.30	2.40	2.80	4.10
11	.....	3.00	5.40	5.90	4.50	2.10	2.30	2.40	2.80	3.75
12	.....	3.00	5.45	5.85	4.50	2.05	2.30	2.40	2.80	3.30
13	3.20	3.00	5.55	5.90	4.45	2.00	2.30	2.40	2.80	2.90
14	3.20	3.15	5.75	6.00	4.65	2.00	2.30	2.40	2.80	2.65
15	3.10	3.25	5.95	6.30	4.75	1.90	2.30	2.40	2.80	2.60
16	3.10	3.60	6.15	6.65	4.75	1.90	2.30	2.50	2.80	2.60
17	3.10	3.85	6.30	6.85	4.60	1.90	2.30	2.50	2.80	2.70
18	3.00	4.10	6.45	7.05	4.45	1.90	2.30	2.60	2.90	2.80
19	3.00	4.50	6.65	7.25	4.40	1.90	2.20	2.60	2.90	2.90
20	3.00	4.80	6.80	7.45	4.35	1.90	2.20	2.60	2.90	3.00
21	3.00	4.90	6.90	7.60	4.20	1.90	2.20	2.60	3.00	3.05
22	3.00	4.90	7.00	7.75	4.00	1.90	2.20	2.65	3.00	3.20
23	2.90	4.90	6.85	7.90	3.80	1.90	2.20	2.70	3.00	3.20
24	2.80	5.05	6.65	7.80	3.65	1.90	2.20	2.70	3.00	3.10
25	2.70	5.25	6.45	7.70	3.45	1.90	2.20	2.70	2.95	3.00
26	2.80	5.50	6.45	7.65	3.35	1.90	2.20	2.80	2.85	3.10
27	2.90	5.80	6.80	7.55	3.25	1.90	2.20	2.80	2.80	3.20
28	2.90	6.20	7.20	7.30	3.20	1.90	2.20	2.80	2.80	3.35
29	2.90	6.50	7.45	7.00	3.10	1.90	2.20	2.80	2.85	3.30
30	2.90	6.85	7.65	6.60	3.00	1.90	2.20	2.80	2.90	3.35
31	2.90	.....	8.00	.....	2.90	1.90	.....	2.80	.....	3.30

Daily gage height, in feet, of Little Wood River at Toponis, Idaho, for 1898.

y .	Mar.	Apr.	Day.	Mar.	Apr.	Day.	Mar.	Apr.	Day.	Mar.	Apr.
1	.....	3.90	9	.....	.....	17	4.20	.....	25	3.90	.....
2	.....	3.90	10	.....	.....	18	4.20	.....	26	3.80	.....
3	.....	3.90	11	.....	.....	19	4.00	.....	27	3.90	.....
4	.....	3.90	12	.....	.....	20	4.00	.....	28	3.90	.....
5	.....	4.10	13	.....	.....	21	4.00	.....	29	3.90	.....
6	.....	4.10	14	.....	.....	22	4.00	.....	30	3.90	.....
7	.....	.....	15	.....	.....	23	4.00	.....	31	3.90	.....
8	.....	.....	16	.....	.....	24	4.00	.....			

Daily gage height, in feet, of Malad River at Toponis, Idaho, for 1898.

Day.	Mar.	Apr.	May.	June	July.	Aug.	Day.	Mar.	Apr.	May.	June	July.	Aug.
1	.....	2.70	4.00	3.90	4.80	1.50	17	2.80	3.90	3.60	4.20	3.00	.....
2	.....	2.70	4.00	4.10	4.80	1.40	18	2.80	3.90	3.60	4.30	3.00	.....
3	.....	2.70	4.00	4.30	4.00	1.40	19	2.70	4.00	3.60	4.60	3.00	.....
4	.....	2.70	4.00	4.40	4.00	1.30	20	2.70	4.20	3.60	4.50	3.00	.....
5	.....	2.70	4.00	4.60	3.90	1.00	21	2.70	4.20	3.60	4.10	2.80	.....
6	.....	2.60	3.80	4.80	3.70	1.00	22	2.70	4.20	3.60	4.30	2.70	.....
7	.....	2.60	3.60	4.50	3.50	.....	23	2.70	4.10	3.70	4.40	2.50	.....
8	.....	2.60	3.40	4.30	3.40	.....	24	2.70	4.20	3.80	4.80	2.40	.....
9	.....	2.60	3.50	4.20	3.30	.....	25	2.70	4.00	3.90	4.40	2.40	.....
10	.....	2.70	3.20	4.00	3.30	.....	26	2.70	4.60	3.90	4.40	2.40	.....
11	.....	3.00	3.40	4.00	3.20	.....	27	2.70	4.20	3.70	4.40	2.00	.....
12	.....	3.60	3.20	4.10	3.20	.....	28	2.70	4.00	3.70	4.40	2.00	.....
13	2.80	3.90	3.40	4.20	3.10	.....	29	2.70	4.00	3.80	4.70	2.00	.....
14	2.80	4.00	3.50	4.20	3.10	.....	30	2.70	4.00	3.90	4.90	1.80	.....
15	2.80	4.00	3.60	4.30	3.00	.....	31	2.70	.....	3.90	.....	1.70	.....
16	2.80	3.90	3.60	4.30	3.00	.....							

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Daily gage height, in feet, of Weiser River at Weiser, Idaho, for 1898.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	D
1	.....	0.80	3.60	3.30	1.90	0.70	0.60	0.60	0.85	[illegible]
2	.....	.90	3.50	3.30	1.90	.60	.60	.60	.85	[illegible]
3	.....	.90	3.40	3.20	1.80	.60	.60	.65	.85	[illegible]
4	.....	.90	3.30	3.10	1.80	.60	.65	.65	.85	[illegible]
5	.....	2.00	3.20	3.00	1.70	.50	.60	.70	.85	[illegible]
6	.....	2.30	3.10	2.90	1.70	.50	.50	.75	.85	[illegible]
7	.....	2.70	3.10	2.90	1.70	.50	.50	.75	.85	[illegible]
8	.....	2.70	3.00	2.80	1.60	.50	.50	.80	.85	[illegible]
9	.....	2.60	3.00	2.80	1.60	.40	.40	.80	.85	[illegible]
10	.....	2.70	3.00	2.80	1.50	.40	.40	.80	.85	[illegible]
11	.....	3.10	3.10	2.70	1.50	.40	.40	.80	.90	[illegible]
12	.....	3.20	3.10	2.70	1.40	.30	.40	.80	.90	[illegible]
13	2.60	3.30	3.10	2.70	1.40	.30	.40	.80	.90	[illegible]
14	2.50	3.50	3.10	2.60	1.30	.30	.40	.80	.95	[illegible]
15	2.40	4.00	3.00	2.60	1.30	.30	.40	.80	.95	[illegible]
16	2.40	4.30	3.00	2.60	1.20	.30	.40	.80	.95	[illegible]
17	2.30	4.40	3.00	2.50	1.20	.30	.40	.80	1.10	[illegible]
18	2.20	4.30	3.00	2.50	1.10	.30	.40	.80	1.00	[illegible]
19	2.10	3.90	3.00	2.50	1.10	.30	.40	.85	.95	[illegible]
20	2.00	3.80	2.90	2.40	1.10	.30	.40	.85	.95	[illegible]
21	1.90	3.70	2.80	2.40	1.00	.20	.40	.85	.95	[illegible]
22	1.80	3.80	2.80	2.40	1.00	.25	.40	.85	.95	[illegible]
23	1.70	3.90	2.70	2.30	1.00	.40	.40	.85	.95	[illegible]
24	1.60	4.00	2.70	2.30	.90	.40	.40	.85	.95	[illegible]
25	1.50	3.90	2.70	2.30	.90	.40	.40	.85	.95	[illegible]
26	1.30	4.00	2.80	2.20	.90	.45	.45	.85	.95	[illegible]
27	1.10	4.40	3.00	2.20	.80	.45	.50	.85	.95	[illegible]
28	1.00	4.20	3.70	2.10	.80	.50	.50	.85	.95	[illegible]
29	.90	3.90	3.60	2.10	.80	.50	.60	.85	.95	[illegible]
30	.80	3.80	3.40	2.00	.70	.50	.60	.85	.95	[illegible]
31	.80	.....	3.30	.....	.70	.50	.....	.85	.....	[illegible]

Daily gage height, in feet, of Palouse River at Hooper, Washington, for 1

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	D
1	7.00	4.20	7.25	6.50	5.65	4.40	2.60	1.95	1.70	1.70	2.10	2
2	6.45	4.20	7.35	6.45	5.40	4.20	2.60	1.80	1.70	1.70	2.10	2
3	6.05	4.35	7.65	6.83	5.15	4.05	2.60	1.60	1.70	1.70	2.10	2
4	5.80	4.50	7.65	6.90	4.95	4.00	2.55	1.65	1.70	1.70	2.05	2
5	5.50	4.75	8.15	6.75	4.65	3.90	2.50	1.75	1.65	1.70	2.05	2
6	5.50	5.45	8.25	6.88	4.75	3.85	2.50	1.80	1.65	1.75	2.05	2
7	5.40	6.20	8.15	7.15	4.90	3.70	2.50	1.80	1.65	1.80	2.05	2
8	5.40	7.10	7.85	7.70	4.75	3.65	2.45	1.80	1.70	1.85	2.10	2
9	5.25	7.20	7.65	7.85	4.70	3.50	2.45	1.70	1.70	1.85	2.15	2
10	4.70	6.40	7.65	7.35	4.50	3.40	2.40	1.70	1.70	1.85	2.20	2
11	4.60	5.90	7.35	7.05	4.40	3.30	2.40	1.70	1.70	1.85	2.20	2
12	4.70	5.80	7.00	7.25	4.35	3.25	2.35	1.70	1.70	1.85	2.10	2
13	4.70	11.00	6.55	7.45	4.30	3.15	2.30	1.65	1.70	1.85	2.10	2
14	4.70	12.00	6.40	7.15	4.25	3.10	2.25	1.60	1.70	1.85	2.10	2
15	4.70	13.00	6.35	7.10	4.25	3.10	2.20	1.60	1.70	1.80	2.05	2
16	4.60	13.99	6.30	7.40	4.20	3.05	2.20	1.65	1.70	1.80	2.05	2
17	4.60	13.29	6.30	7.80	4.15	3.05	2.20	1.75	1.70	1.80	2.05	1
18	4.70	12.54	6.15	7.75	4.05	3.05	2.20	1.80	1.70	1.80	2.10	2
19	4.90	10.84	6.00	7.40	3.95	3.00	2.20	1.90	1.70	1.85	2.15	2
20	4.70	9.54	5.90	7.00	3.95	3.00	2.20	1.80	1.70	1.90	2.15	2
21	4.50	9.14	5.90	6.53	3.90	3.00	2.20	1.80	1.70	1.85	2.20	2
22	4.45	8.85	5.85	6.45	3.85	2.95	2.20	1.70	1.70	1.85	2.35	2
23	4.35	8.55	5.45	6.45	3.75	2.90	2.20	1.70	1.70	1.85	2.40	2
24	4.00	8.15	5.30	6.55	3.70	2.80	2.20	1.70	1.70	1.85	2.50	2
25	4.10	7.95	5.40	6.65	3.65	2.75	2.15	1.70	1.70	2.00	2.45	2
26	4.15	7.65	5.55	6.55	3.65	2.75	2.15	1.70	1.70	2.00	2.35	2
27	4.15	7.35	5.30	6.30	4.05	2.75	2.10	1.70	1.70	2.05	2.30	2
28	4.20	7.25	5.30	6.35	4.05	2.70	2.05	1.70	1.70	2.05	2.20	2
29	4.10	.....	5.30	6.40	4.00	2.60	2.05	1.70	1.70	2.05	2.20	2
30	4.10	.....	5.40	6.10	4.35	2.60	2.00	1.70	1.70	2.05	2.25	2
31	4.25	.....	5.70	.....	4.40	.....	1.95	1.70	.....	2.10	.....	2

Daily gage height, in feet, of Blackfoot River at Bonner, Montana, for 1898.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	1.80	.95	.90	.85	.80	17	2.75	1.30	.95	.85	.85	.....
2	.....	1.85	1.15	1.10	.85	.80	18	2.65	1.25	.90	.95	.85	.....
3	.....	1.70	1.15	.90	.80	.75	19	2.60	1.30	.95	1.00	.90	.....
4	.....	1.60	1.05	.85	.95	.70	20	2.45	1.30	.90	1.25	.80	.....
5	.....	1.50	1.05	.95	.90	.75	21	2.40	1.25	.90	1.00	.75	.....
6	.....	1.60	1.10	.85	1.25	1.30	22	2.35	1.25	1.00	1.25	.80	.....
7	4.00	1.60	1.05	.70	1.00	.90	23	2.25	1.20	1.05	.85	.75	.....
8	3.65	1.60	1.10	.70	.75	1.40	24	2.25	1.20	1.25	1.25	.80	.....
9	3.50	1.50	1.05	.80	.85	1.40	25	2.20	1.15	1.05	1.20	.85	.....
10	3.45	1.55	1.00	.80	.90	3.40	26	2.15	1.15	1.05	1.40	.85	.....
11	3.35	1.50	.95	.65	.95	(a)	27	2.05	1.20	1.05	1.05	.70	.....
12	3.25	1.70	.95	1.15	.90	(a)	28	1.95	1.20	1.00	1.40	.80	.....
13	3.05	1.40	1.05	.75	.90	(a)	29	1.95	1.05	.95	1.10	.90	.....
14	3.00	1.40	1.05	1.15	.95	(a)	30	1.90	1.05	.85	1.05	.70	.....
15	2.95	1.25	1.15	1.10	.95	(a)	31	1.80	1.05	.....	1.35	.....	.....
16	2.85	1.30	1.00	.85	.85	.....							

a Ice.

Daily gage height, in feet, of Bitterroot River at Missoula, Montana, for 1898.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	2.45	1.40	1.50	1.75	1.60	17	4.00	1.60	1.35	1.85	1.55	.....
2	.....	2.30	1.50	1.45	1.75	1.60	18	3.80	1.60	1.30	1.80	1.60	.....
3	.....	2.25	1.70	1.45	1.75	1.50	19	3.60	1.60	1.25	1.80	1.75	.....
4	.....	2.15	1.70	1.50	1.75	1.40	20	3.40	1.60	1.20	1.75	1.70	.....
5	.....	2.10	1.75	1.45	1.80	1.40	21	3.20	1.45	1.15	1.70	1.70	.....
6	5.40	2.00	1.70	1.45	1.80	1.40	22	3.10	1.40	1.20	1.65	1.55	.....
7	5.15	1.95	1.65	1.45	1.85	1.80	23	3.00	1.45	1.35	1.85	1.65	.....
8	4.90	1.90	1.60	1.45	1.85	2.00	24	3.10	1.45	1.35	1.85	1.70	.....
9	4.75	1.85	1.55	1.45	1.85	2.30	25	2.90	1.40	1.40	1.85	1.65	.....
10	4.75	1.85	1.50	1.45	1.80	2.30	26	2.85	1.40	1.45	1.85	1.60	.....
11	4.70	1.75	1.45	1.50	1.75	.....	27	2.80	1.35	1.50	1.85	1.60	.....
12	4.65	1.75	1.45	1.60	1.70	.....	28	2.65	1.35	1.45	1.85	1.60	.....
13	4.65	1.60	1.40	1.55	1.65	.....	29	2.60	1.35	1.45	1.90	1.55	.....
14	4.50	1.60	1.35	1.55	1.65	.....	30	2.55	1.30	1.45	1.80	1.55	.....
15	4.40	1.60	1.35	1.55	1.55	.....	31	2.50	1.35	.....	1.80	.....	.....
16	4.20	1.60	1.35	1.85	1.55	.....							

Daily gage height, in feet, of Missoula River at Missoula, Montana, for 1898.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	3.45	2.75	2.75	2.75	2.65	17	4.53	2.85	2.73	2.75	2.60	.....
2	.....	3.40	2.80	2.75	2.75	2.65	18	4.45	2.85	2.70	2.75	2.68	.....
3	.....	3.35	2.80	2.75	2.75	2.65	19	4.38	2.85	2.68	2.78	2.70	.....
4	.....	3.28	2.80	2.75	2.75	2.65	20	4.23	2.85	2.65	2.80	(a)	.....
5	.....	3.23	2.80	2.75	2.78	(a)	21	4.08	2.80	2.65	2.75	(a)	.....
6	.....	3.20	2.85	2.75	2.80	(a)	22	3.95	2.80	2.73	2.75	(a)	.....
7	.....	3.18	2.80	2.75	2.75	(a)	23	3.95	2.80	2.75	2.78	(a)	.....
8	.....	3.13	2.80	2.75	2.75	(a)	24	4.00	2.80	2.75	2.80	2.75	.....
9	.....	3.05	2.80	2.75	2.70	(a)	25	3.95	2.78	2.75	2.83	2.75	.....
10	5.28	3.05	2.80	2.75	2.70	(a)	26	3.90	2.75	2.70	2.80	2.75	.....
11	5.13	3.00	2.75	2.90	2.70	.....	27	3.75	2.75	2.70	2.80	2.75	.....
12	4.98	2.95	2.75	2.83	2.65	.....	28	3.68	2.75	2.70	2.80	2.75	.....
13	4.85	2.90	2.75	2.75	2.65	.....	29	3.60	2.70	2.75	2.80	2.75	.....
14	4.80	2.90	2.75	2.75	2.65	.....	30	3.53	2.70	2.75	2.80	2.75	.....
15	4.73	2.88	2.75	2.75	2.60	.....	31	3.50	2.73	.....	2.80	.....	.....
16	4.63	2.85	2.75	2.75	2.60	.....							

a Ice.

Daily gage height, in feet, of Lake Chelan, Lakeside, Washington, for 1897.

Day.	Sept.	Oct.	Day.	Sept.	Oct.	Day.	Sept.	Oct.	Day.	Sept.	Oct.
1	8.15	7.18	8	7.90	7.05	15	7.40	.....	22	7.33	.....
2	8.10	7.15	9	7.95	7.03	16	7.38	.....	23	7.32	.....
3	8.65	7.15	10	7.90	7.02	17	7.35	.....	24	7.30	.....
4	8.70	7.12	11	7.65	.....	18	7.33	.....	25	7.30	.....
5	8.00	7.10	12	7.55	.....	19	7.35	.....	26	7.28	.....
6	8.10	7.08	13	7.50	7.00	20	7.33	.....	27	7.25	.....
7	8.00	7.07	14	7.45	7.00	21	7.33	.....	30	7.20	.....

Daily gage height, in feet, of Spokane River at Spokane, Washington, for

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	5.60	3.00	6.70	4.35	10.40	9.90	5.85	2.95	2.00	1.75	1.95
2	5.70	3.00	6.60	4.30	10.40	9.85	5.70	2.90	2.00	1.75	2.00
3	5.70	2.90	6.50	4.25	10.35	9.80	5.50	2.85	2.00	1.75	2.00
4	5.65	2.90	6.40	4.20	10.25	9.65	5.40	2.80	1.90	1.75	2.05
5	5.60	2.95	6.45	4.25	10.10	9.40	5.25	2.75	1.90	1.75	2.10
6	5.45	2.95	6.55	4.30	10.10	9.25	5.10	2.70	1.85	1.75	2.10
7	5.35	3.00	6.60	4.45	9.95	9.10	4.95	2.70	1.80	1.75	2.15
8	5.25	3.20	6.65	4.60	9.90	9.00	4.80	2.65	1.80	1.75	2.15
9	5.10	3.50	6.70	4.75	9.75	8.85	4.70	2.60	1.80	1.80	2.20
10	5.00	3.90	6.70	4.90	9.60	8.80	4.55	2.55	1.80	1.75	2.20
11	4.90	4.10	6.70	5.10	9.40	8.75	4.45	2.50	1.80	1.75	2.25
12	4.70	4.30	6.65	5.30	9.40	8.65	4.40	2.50	1.80	1.75	2.25
13	4.60	4.50	6.60	5.50	9.45	8.60	4.30	2.45	1.80	1.75	2.25
14	4.50	4.65	6.50	5.70	9.55	8.50	4.20	2.40	1.80	1.75	2.25
15	4.40	5.40	6.40	6.10	9.60	8.45	4.15	2.35	1.80	1.75	2.25
16	4.30	6.40	6.30	6.50	9.70	8.40	4.00	2.35	1.80	1.80	2.25
17	4.20	7.10	6.10	7.10	9.80	8.20	3.90	2.30	1.80	1.85	2.20
18	4.10	7.80	6.00	7.50	9.95	8.00	3.85	2.30	1.80	1.85	2.20
19	4.00	8.20	5.90	7.70	10.10	7.90	3.80	2.25	1.80	1.85	2.20
20	4.00	8.20	5.80	7.90	10.20	7.80	3.70	2.20	1.80	1.85	2.20
21	3.90	8.10	5.50	8.10	10.10	7.60	3.65	2.20	1.80	1.90	2.20
22	3.80	8.10	5.50	8.20	10.00	7.40	3.55	2.20	1.75	1.90	2.25
23	3.70	7.80	5.40	8.40	9.80	7.25	3.50	2.20	1.75	1.90	2.25
24	3.60	7.60	5.20	8.60	9.55	7.05	3.40	2.20	1.75	1.90	2.25
25	3.50	7.50	5.10	8.75	9.40	6.95	3.30	2.15	1.75	1.90	2.25
26	3.40	7.30	5.00	8.80	9.20	6.80	3.30	2.10	1.75	1.90	2.25
27	3.35	7.10	4.90	9.15	9.15	6.60	3.20	2.10	1.75	1.90	2.25
28	3.30	6.80	4.80	9.60	9.15	6.40	3.15	2.05	1.75	1.90	2.25
29	3.20	.....	4.65	10.15	9.30	6.15	3.10	2.00	1.75	1.95	2.20
30	3.15	.....	4.50	10.30	9.60	5.95	3.05	2.00	1.75	1.95	2.20
31	3.05	.....	4.40	.....	9.80	.....	3.00	2.00	.....	1.95	.....

Daily gage height, in feet, of Wallawalla River at Whitman, Washington, fo

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	2.85	2.00	2.88	2.50	3.28	2.25	1.20	1.05	1.10	1.30	1.50
2	2.68	2.00	2.80	2.80	3.23	2.20	1.20	1.05	1.10	1.30	1.50
3	2.70	2.00	2.75	2.80	3.13	2.20	1.20	1.05	1.10	1.35	1.50
4	2.63	2.05	2.75	2.80	3.05	2.15	1.20	1.03	1.15	1.35	1.50
5	2.50	2.10	2.68	3.20	2.98	2.10	1.20	1.00	1.15	1.35	1.50
6	2.75	2.60	2.60	3.85	2.88	2.05	1.20	1.00	1.20	1.35	1.50
7	2.90	3.10	2.68	3.63	2.75	2.00	1.15	1.00	1.20	1.40	1.50
8	2.93	3.80	2.78	3.38	2.70	1.95	1.15	1.00	1.20	1.40	1.50
9	2.90	3.32	2.68	3.25	2.65	1.88	1.15	1.00	1.20	1.40	1.50
10	2.73	2.95	2.58	3.60	2.60	1.73	1.15	1.00	1.15	1.40	1.50
11	2.63	2.80	2.48	3.53	2.63	1.65	1.15	1.00	1.15	1.40	1.50
12	2.55	2.88	2.45	3.73	2.68	1.65	1.15	1.00	1.15	1.45	1.50
13	2.50	3.08	2.45	3.80	2.58	1.65	1.15	1.00	1.10	1.45	1.50
14	2.45	4.23	2.40	3.80	2.50	1.65	1.15	1.00	1.10	1.45	1.50
15	2.43	4.85	2.35	3.75	2.45	1.65	1.15	1.00	1.10	1.45	1.50
16	2.40	4.75	2.30	3.63	2.43	1.65	1.15	1.00	1.13	1.45	1.50
17	2.35	4.00	2.23	3.55	2.40	1.65	1.15	1.00	1.13	1.45	1.55
18	2.30	4.18	2.20	3.33	2.35	1.63	1.10	1.00	1.13	1.45	1.55
19	2.30	3.18	2.20	3.20	2.35	1.60	1.10	1.00	1.15	1.45	1.65
20	2.35	3.00	2.18	3.35	2.30	1.55	1.10	1.00	1.15	1.45	1.75
21	2.35	3.05	2.10	3.53	2.25	1.50	1.10	1.00	1.15	1.45	1.83
22	2.38	2.90	2.05	3.65	2.43	1.45	1.10	1.00	1.20	1.45	1.90
23	2.18	2.70	2.05	3.60	2.33	1.40	1.10	1.00	1.20	1.45	1.90
24	2.00	2.68	2.10	3.55	2.25	1.35	1.10	1.05	1.20	1.45	1.90
25	2.00	2.63	2.05	3.55	2.25	1.30	1.10	1.05	1.25	1.45	1.90
26	2.00	2.55	2.05	4.40	2.28	1.25	1.10	1.10	1.25	1.45	1.80
27	2.00	2.50	2.05	4.10	2.45	1.20	1.10	1.10	1.25	1.50	1.80
28	2.00	2.73	2.05	3.83	2.58	1.20	1.10	1.10	1.25	1.50	1.80
29	2.08	.....	2.05	3.63	2.53	1.20	1.08	1.10	1.25	1.50	1.80
30	2.00	.....	2.05	3.30	2.43	1.25	1.05	1.10	1.25	1.50	1.80
31	2.00	.....	2.25	.....	2.33	.....	1.05	1.10	.....	1.50	.....

ily gage height, in feet, of Yakima River at Union Gap, Washington, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	8.00	5.20	7.00	6.00	8.80	7.80	6.90	5.50	4.40	4.60	4.80	5.20
2	7.70	5.20	7.00	6.00	8.80	8.00	6.80	5.40	4.40	4.60	4.80	5.20
3	7.40	5.20	7.00	6.00	8.80	7.80	6.80	5.30	4.40	4.60	4.90	5.10
4	7.20	5.20	7.10	6.10	9.20	7.60	7.00	5.30	4.40	4.70	5.10	5.10
5	7.00	5.20	7.50	6.10	9.20	7.60	6.70	5.30	4.40	4.60	5.30	5.10
6	6.80	5.80	7.60	6.30	9.20	8.00	6.80	5.20	4.40	4.60	5.30	4.90
7	6.60	6.00	7.60	6.60	9.00	8.60	6.70	5.10	4.30	4.60	5.30	4.80
8	6.50	6.20	7.30	6.60	9.00	9.00	6.60	5.10	4.30	4.60	5.70	4.70
9	6.40	6.10	7.20	6.60	8.00	9.30	6.50	5 10	4.30	4.60	5.70	4.70
10	6.20	6.10	7.10	6.70	8.50	9.50	6.40	5.10	4.30	4.60	5.60	4.60
11	6.10	6.00	7.10	7.10	9.10	9.70	6.50	5.00	4.30	4.60	5.50	4.60
12	6.10	6.00	7.00	7.20	9.20	9.20	6.50	5.00	4.30	4.60	5.40	4.60
13	6 00	5.90	6.90	7.30	9.40	9.10	6.50	4.90	4.30	4.70	5.20	4.70
14	5.90	9.00	6.80	7.80	9.40	9.10	6.50	4.80	4.30	4.20	5.20	4.70
15	5.90	11.10	6.80	7.20	9.70	9.00	6.50	4.80	4.20	4.20	5.20	4.70
16	5.90	10 80	6.70	7.20	10.00	9.10	6.50	4.80	4.20	5.20	5.10	4.80
17	5 80	10.10	6.60	8.20	10.20	8.70	6.20	4.70	4.20	5.20	5.10	4.80
18	5.70	9.30	6.50	8.20	10.40	8.50	6.10	4.70	4.30	5.20	5.60	4.70
19	5.70	8.60	6.40	8.00	10.20	8.50	6.00	4.70	4.30	5.20	5.80	4.70
20	5.60	8.60	6.40	7.90	9.60	8.60	6.00	4.60	4.30	5.20	5.80	4.70
21	5.60	8.10	6.40	7.80	9.10	8.50	5.90	4.60	4.40	5.10	5.70	4.60
22	5.60	7.80	6.30	7.80	9.00	8.30	5.80	4.60	4.40	5.00	5.60	4.60
23	5.50	7 60	6.30	7.80	8.50	7.80	5.70	4.60	4.50	5.00	5.50	4.60
24	5.50	7.40	6.20	8.20	8.20	7.60	5.60	4.50	4.50	5.00	5.40	4.60
25	5.50	7.20	6.20	8.20	8.10	7.60	5.60	4.50	4.50	4.90	5.30	4.60
26	5.40	7.10	6.10	8.80	8.10	7.50	5.50	4.50	4.50	4.90	5.30	4.50
27	5.40	7.00	6.10	9.10	8.10	7.40	5.50	4.50	4.50	4.80	5.20	4.50
28	5.40	7.00	6.00	9.00	8.70	7.30	5.50	4.50	4.50	4.80	5.20	6.80
29	5.30	.....	6.00	8.90	9.00	7.20	5.50	4.40	4.50	4.80	5.30	8.50
30	5.30	.....	5.90	9.00	8.60	7.00	5.50	4.40	4.50	4.80	5.20	7.80
31	5.30	.....	5.90	.....	8.30	.....	5.50	4.40	.....	4.80	.....	7.30

Daily gage height, in feet, of Yakima River at Kiona, Washington, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	10.15	5.60	7.72	6.10	10.18	9.10	7.25	5.19	.....	4.18	4.56	5.05
2	9.55	5.50	7.72	6.19	10.10	8.95	7.10	5.20	4.02	4.21	4.51	5.00
3	9.00	5.46	7.73	.....	10.00	8.73	.....	5.14	4.00	4.25	4.56	5.00
4	8.55	5.35	.....	6.15	10.08	8.50	.....	5.10	3.95	4.27	4.68	4.96
5	8.20	5.32	7.85	6.15	10.45	8.38	.....	5.17	3.90	4.30	4.96	4.90
6	7.90	5.60	7.98	.....	10.55	8.61	.....	5.03	3.95	4.31	4.95	4.85
7	7.60	6.05	8.02	6.50	.....	9.23	.....	5.04	3.92	4.33	5.32	4.60
8	7.35	6.72	8.15	6.82	10.23	9.79	7.05	4.90	3.90	4.29	5.40	4.53
9	7.10	6.80	8.18	6.82	9.85	10.19	6.71	4.88	3.87	4.25	5.56	4.20
10	6.90	6.60	7.98	6.76	9.66	10.50	6.67	4.82	3.84	4.20	5.50	4.40
11	6.60	6.60	7.91	6.85	10.08	10.72	.....	4.80	.....	4.22	5.41	4.40
12	6.50	6.70	7.75	6.90	10.51	10.90	6.68	4.75	.....	4.24	5.34	4.35
13	6.50	6.72	7.82	7.00	10.75	10.56	6.66	.....	3.79	4.30	5.24	4.05
14	6.45	6.75	7.75	7.61	10.78	10.13	6.55	.....	3.76	4.35	5.12	4.10
15	6.30	11.25	.....	8.32	10.83	10.02	6.54	.....	3.78	4.35	5.04	4 15
16	6.20	12.45	7.42	8.95	.....	10.17	6.40	4.43	3.78	4.60	4.94	4.40
17	6.12	13.27	7.30	9.20	.....	10.14	6.29	4.34	3.77	4.93	4.95	4.45
18	6.04	13.21	7.15	9.21	12.00	9.76	6.17	4.29	3.74	4.95	4.90	4.64
19	6.00	12.07	6.93	9.05	12.10	9.45	6.05	4.27	3.71	5.00	5.22	4.75
20	5.95	10.92	6.93	8.95	11.85	9.65	6.03	4.26	3.69	5.02	5.50	4.60
21	5.90	10.10	6.82	8.75	10.80	9.50	5.98	.....	3.76	4.93	5.56	4.56
22	5.85	9.62	6.73	8 65	10 20	9.15	5.78	4.20	3.78	4.86	5.60	4.50
23	5.80	9.20	6.64	8.62	9.82	8.60	5.69	4.17	3.80	4.88	5.50	4.45
24	5.75	8.72	6.50	8 82	9.60	8.37	5.67	4.16	3.84	4.72	5.40	4.40
25	5.70	8.46	6 53	9.00	9.36	8.26	5.52	4.17	3.80	4.68	5.25	4.44
26	5.10	8.33	6.47	9.45	9.06	8.20	5.50	4.13	3.84	4.63	5.20	4.45
27	5.20	7.98	6.38	10.20	9.50	7.94	5.46	4.10	3.87	4.60	5.15	4.75
28	5.15	7.76	6.28	10.29	10.02	7.82	5.44	4.10	3.90	4.57	5.10	4.90
29	5.10	.....	6.18	10.23	10.08	7.62	5.42	4.08	4.00	4.53	5.15	7.50
30	5.35	.....	6.14	10.18	9.80	7.42	5.33	4.04	4.10	4.56	5.10	8.50
31	5.52	.....	6.10	.....	9.51	.....	5.24	4.01	.....	4.54	.....	8.15

Daily gage height, in feet, of Hood River at Tucker, Oregon, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec
1	4.60	2.60	3.50	2.40	3.50	3.20	2.50	2.40	1.70	2.40	1.60	4.4
2	4.60	2.50	3.50	2.40	3.50	3.10	2.50	2.40	1.60	2.20	1.60	4.2
3	4.00	2.50	3.50	2.40	3.50	2.90	2.60	2.30	1.60	2.20	2.00	4.0
4	3.90	2.70	3.50	2.40	3.40	2.80	2.60	2.20	1.60	2.10	4.00	3.8
5	3.80	3.60	3.40	2.40	3.40	2.90	2.60	2.20	1.60	1.90	3.60	3.6
6	4.00	4.60	3.40	2.40	3.30	3.30	2.50	2.20	1.60	1.90	3.00	3.2
7	3.60	5.60	3.50	2.70	3.30	3.40	2.50	2.20	1.60	1.80	2.80	3.0
8	3.50	4.80	3.50	2.70	3.30	3.40	2.50	2.20	1.60	1.70	2.60	2.8
9	3.40	4.60	3.40	2.60	3.40	3.50	2.50	2.20	1.60	1.80	2.50	2.4
10	3.20	4.00	3.30	2.60	3.40	3.40	2.60	2.30	1.80	2.00	2.30	2.2
11	3.00	3.80	3.20	2.50	3.40	3.40	2.60	2.40	1.80	2.00	2.00	2.2
12	3.00	5.20	3.20	2.60	3.50	3.40	2.60	2.30	1.70	2.00	2.00	2.1
13	3.00	6.00	3.10	3.00	3.50	3.40	2.70	2.20	1.70	2.00	1.90	2.0
14	3.10	8.70	3.00	3.40	3.60	3.40	2.50	2.20	1.70	2.00	1.90	2.0
15	3.20	8.60	3.00	3.50	3.50	3.40	2.40	2.20	1.70	3.30	1.90	2.0
16	3.30	7.60	3.00	3.50	3.40	3.30	2.40	2.10	1.70	2.80	1.90	2.1
17	3.20	6.00	2.80	3.40	3.40	3.20	2.70	2.00	1.70	2.60	4.00	2.1
18	3.20	5.30	2.70	3.20	3.40	3.20	2.50	2.00	1.80	2.50	6.00	2.3
19	4.00	4.50	2.60	3.10	3.40	3.20	2.30	1.90	1.80	2.30	4.80	3.1
20	3.70	4.30	2.60	3.20	3.40	3.10	2.20	1.80	1.80	2.10	4.30	2.7
21	3.30	4.50	2.80	3.20	3.50	3.10	2.20	1.80	2.60	2.00	3.00	2.6
22	3.20	4.10	2.60	3.50	3.60	3.00	2.20	1.90	2.20	1.90	2.90	2.5
23	3.20	4.00	2.60	4.00	3.40	2.90	2.40	1.90	2.60	1.90	2.80	2.3
24	3.00	3.80	2.70	4.00	3.30	2.80	2.30	2.00	1.80	1.80	2.70	2.2
25	3.00	3.50	2.60	4.10	3.30	2.80	2.30	2.00	1.60	1.70	2.60	2.3
26	3.00	3.50	2.50	4.70	3.30	2.80	2.20	2.00	1.60	1.70	2.60	3.3
27	2.90	3.50	2.50	4.30	3.30	2.80	2.20	2.00	1.60	1.70	2.60	3.6
28	2.80	3.50	2.50	4.00	3.20	2.70	2.30	2.00	1.60	1.70	2.10	5.00
29	2.60	.....	2.50	3.90	3.20	2.60	2.30	1.90	2.20	1.70	3.00	4.8
30	2.70	.....	2.50	3.80	3.10	2.50	2.40	1.80	3.20	1.60	3.50	4.5
31	2.70	.....	2.40	.....	3.00	.....	2.50	1.70	.....	1.60	.....	4.3

List of discharge measurements, 1898.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
				Feet.	*Sec.-ft.*
Mar. 16	Portneuf River	Pocatello, Idaho	F. J. Mills	7.85	286
Apr. 28	do	do	do	8.90	562
June 14	do	do	do	7.75	293
July 31	do	do	C. C. Babb	6.40	47
Do.	do	do	do	6.70	87
Oct. 9	do	do	F. S. Shirley	6.90	143
Aug. 26	Snake River	Montgomery, Idaho	C. C. Babb	1.90	2,831
Oct. 11	do	do	F. S. Shirley	2.50	5,110
Mar. 17	Malad River	Toponis, Idaho	F. J. Mills	2.80	72
May 22	do	do	do	3.60	324
Mar. 17	Little Wood River	do	do	4.20	127
Oct. 10	do	do	F. S. Shirley	3.10	63
Apr. 16	Boise River	Boise, Idaho	F. J. Mills	4.20	5,248
June 15	do	do	F. S. Shirley	4.20	6,710
Aug. 3	do	do	C. C. Babb	1.25	872
Aug. 24	do	do	do	1.00	698
Oct. 18	do	do	F. S. Shirley	1.20	845
Apr. 12	Weiser River	Weiser, Idaho	F. J. Mills	3.20	1,914
June 2	do	do	do	3.30	2,305
Aug. 6	do	do	C. C. Babb	.40	42
Oct. 14	do	do	F. S. Shirley	.80	172
Mar. 10	Palouse River	Hooper, Wash	Sydney Arnold	7.50	2,779
June 21	do	do	do	3.00	223
July 7	Blackfoot River	Bonner, Mont	C. C. Babb	4.00	5,518
July 13	do	do	M. J. Elrod	3.10	3,357
July 25	do	do	do	2.20	2,038
Aug. 12	do	do	do	1.50	1,236
Sept. 3	do	do	do	1.10	1,055
Oct. 1	do	do	do	1.00	917
Nov. 5	do	do	Fred. D. Smith	.90	913
July 6	Bitterroot River	Missoula, Mont	C. C. Babb	5.40	7,957
July 13	do	do	M. J. Elrod	4.60	5,456
July 25	do	do	do	2.90	2,579
Aug. 12	do	do	do	1.75	1,100
Sept. 3	do	do	do	1.70	1,280
Oct. 1	do	do	do	1.50	1,061
Nov. 5	do	do	Fred. D. Smith	1.90	1,483

List of discharge measurements, 1898—Continued.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
				Feet.	*Sec.-ft.*
Oct. 29	Bitterroot River	Harlan Bridge, near Como, Mont.	C. C. Babb		333
Dec. 26	do	Hamilton, Mont.	H. S. Lord		430
July 5	Missoula River	Missoula, Mont	C. C. Babb	6.15	10,674
July 16	do	do	M. J. Elrod	4.65	5,381
July 30	do	do	do	3.50	3,064
Aug. 19	do	do	do	2.85	1,849
Sept. 15	do	do	do	2.82	1,871
Oct. 22	do	do	do	2.75	1,912
Sept. 8	Yakima River	Union Gap, Wash.	C. C. Babb	4.30	786
Sept. 29	do	do	Sydney Arnold	4.50	985
Jan. 31	do	Kiona, Wash	do	5.52	2,409
Apr. 26	do	do	do	9.45	10,585
May 25	do	do	do	9.27	9,548
July 8	do	do	do	7.04	5,207
July 21	do	do	do	6.05	3,308
Aug. 4	do	do	do	5.20	1,815
Aug. 19	do	do	do	4.27	1,011
Sept. 6	Spokane River	Spokane, Wash	do	1.80	2,715
Oct. 8	do	do	C. C. Babb	1.75	2,202
May 7	Umatilla River	Gibbon, Oreg	Sydney Arnold	2.30	981
Oct. 8	do	do	do	.30	83
May 6	Deschutes River	Moro, Oreg	do	2.60	7,582
May 5	Hood River	Tucker, Oreg	do	3.45	1,502

Rating tables.

Pocatello.		Montgomery.		Toponis. *a*		Toponis. *b*		Grandview.		Boise.	
Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage h'g't.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
6.4	47	2.0	4,400	2.0	0	1.0	0	1.0	10	1.0	550
6.6	80	2.2	4,525	2.1	5	1.2	1	1.1	25	1.1	721
6.8	113	2.4	4,700	2.2	10	1.4	3	1.2	45	1.2	892
7.0	147	2.6	4,900	2.3	15	1.6	5	1.3	55	1.3	1,063
7.2	183	2.8	5,100	2.4	20	1.8	9	1.4	65	1.4	1,234
7.4	219	3.0	5,400	2.5	30	2.0	14	1.5	80	1.5	1,405
7.6	257	3.2	5,800	2.6	45	2.2	19	1.6	100	1.6	1,576
7.8	296	3.4	6,200	2.7	60	2.4	27	1.7	120	1.7	1,747
8.0	336	3.6	6,600	2.8	80	2.6	37	1.8	140	1.8	1,918
8.2	384	3.8	7,000	2.9	100	2.8	47	1.9	170	1.9	2,089
8.4	433	4.0	7,400	3.0	130	3.0	57	2.0	200	2.0	2,260
8.6	484	4.5	8,900	3.2	210	3.2	70	2.1	230	2.2	2,602
8.8	536	5.0	11,000	3.4	320	3.4	87	2.2	270	2.4	2,944
9.0	590	5.5	13,400	3.6	460	3.6	105	2.3	310	2.6	3,286
9.2	650	6.0	15,800	3.8	600	3.8	126	2.4	360	2.8	3,628
9.4	711	6.5	18,200	4.0	740	4.0	150	2.5	410	3.0	3,970
9.6	777	7.0	20,600	4.2	910	4.2	173	2.6	470	3.2	4,312
9.8	848	7.5	23,000	4.4	1,090	4.4	196	2.7	540	3.4	4,654
10.0	920	8.0	25,400	4.6	1,290	4.6	219	2.8	620	3.6	4,996
10.2	988	8.5	27,800	4.8	1,490	4.8	243	2.9	700	3.8	5,338
10.4	1,057	9.0	30,200	5.0	1,700	5.0	266	3.0	780	4.0	5,680
10.6	1,126	9.5	32,600	5.2	1,920	5.2	289	3.1	850	4.2	6,022
10.8	1,194	10.0	35,000	5.4	2,140	5.4	312	3.2	920	4.4	6,364
11.0	1,263	10.5	37,400	5.6	2,360	5.6	335	3.3	1,000	4.6	6,706
11.2	1,331	11.0	39,800	5.8	2,580	5.8	358	3.4	1,080	4.8	7,048
11.4	1,400	11.5	42,200	6.0	2,800	6.0	382	3.5	1,160	5.0	7,390
11.6	1,469	12.0	44,600	6.2	3,020	6.2	405	4.0	1,610	5.2	7,732
11.8	1,537	12.5	47,000	6.4	3,240	6.4	418	5.0	2,300	5.4	8,074
12.0	1,606	13.0	49,400	6.6	3,460	6.6	451	6.0	3,060	5.6	8,416
13.0	1,950			6.8	3,680	6.8	474	7.0	3,850	5.8	8,758

a Rating table for Malad River. *b* Rating table for Little Wood River.

Rating tables—Continued.

Weiser.		Hooper.		Bonner.		Missoula.*a*		Missoula.*b*	
Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
0.6	80	1.5	10	0.7	850	1.3	950	2.6	1,620
.8	120	1.6	20	.8	875	1.4	1,000	2.7	1,740
1.0	190	1.7	30	.9	900	1.5	1,050	2.8	1,870
1.2	280	1.8	40	1.0	950	1.6	1,100	2.9	2,000
1.4	390	1.9	50	1.1	1,000	1.7	1,150	3.0	2,150
1.6	510	2.0	61	1.2	1,060	1.8	1,230	3.1	2,310
1.8	650	2.2	86	1.3	1,120	1.9	1,325	3.2	2,500
2.0	800	2.4	115	1.4	1,185	2.0	1,425	3.3	2,690
2.2	970	2.6	148	1.5	1,250	2.2	1,625	3.4	2,870
2.4	1,150	2.8	185	1.6	1,340	2.4	1,860	3.5	3,070
2.6	1,340	3.0	226	1.7	1,440	2.6	2,150	3.6	3,260
2.8	1,540	3.5	347	1.8	1,550	2.8	2,450	3.7	3,450
3.0	1,760	4.0	525	1.9	1,675	3.0	2,750	3.8	3,640
3.2	1,995	4.5	800	2.0	1,800	3.2	3,050	3.9	3,830
3.4	2,250	5.0	1,130	2.1	1,925	3.4	3,350	4.0	4,020
3.6	2,525	5.5	1,460	2.2	2,050	3.6	3,650	4.1	4,210
3.8	2,820	6.0	1,790	2.3	2,175	3.8	3,950	4.2	4,410
4.0	3,135	6.5	2,120	2.4	2,305	4.0	4,250	4.3	4,610
4.2	3,465	7.0	2,450	2.5	2,440	4.2	4,580	4.4	4,820
4.4	3,875	7.5	2,780	2.6	2,575	4.4	4,970	4.5	5,030
4.6	4,305	8.0	3,110	2.7	2,715	4.6	5,450	4.6	5,250
4.8	4,775	8.5	3,440	2.8	2,860	4.8	6,070	4.7	5,490
5.0	5,285	9.0	3,770	2.9	3,010	5.0	6,690	4.8	5,740
5.5	6,735	9.5	4,100	3.0	3,180	5.2	7,310	4.9	6,000
6.0	8,400	10.0	4,430	3.2	3,540	5.4	7,930	5.0	6,300
6.5	10,155	10.5	4,760	3.4	3,925	5.6	8,550	5.2	6,950
7.0	11,950	11.0	5,090	3.6	4,400	5.8	9,170	5.4	7,690
7.5	13,785	12.0	5,750	3.8	4,920	6.0	9,810	5.6	8,470
8.0	15,640	13.0	6,410	4.0	5,520	6.2	10,450	5.8	9,250
.....	.....	14.0	7,070	4.2	6,120	.....	.....	6.0	10,040

a Rating table for Bitterroot River.
b Rating table for Missoula River.

North Yakima.		Union Gap.		Kiona.		Spokane.		Gibbon.	
Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
4.0	385	4.0	520	3.5	525	1.0	1,341	0.0	56
4.1	445	4.2	685	3.6	566	1.2	1,611	.1	65
4.2	505	4.4	885	3.7	612	1.4	1,897	.2	74
4.3	607	4.6	1,085	3.8	663	1.6	2,199	.3	83
4.4	709	4.8	1,315	3.9	719	1.8	2,517	.4	92
4.5	811	5.0	1,545	4.0	780	2.0	2,851	.5	106
4.6	913	5.2	1,775	4.2	916	2.5	3,754	.6	124
4.7	1,019	5.4	2,028	4.4	1,071	3.0	4,749	.7	146
4.8	1,132	5.6	2,320	4.6	1,245	3.5	5,832	.8	172
4.9	1,252	5.8	2,644	4.8	1,438	4.0	7,000	.9	202
5.0	1,380	6.0	3,000	5.0	1,650	4.5	8,245	1.0	233
5.1	1,515	6.2	3,388	5.2	1,878	5.0	9,565	1.2	298
5.2	1,658	6.4	3,808	5.4	2,122	5.5	10,957	1.4	372
5.3	1,808	6.6	4,258	5.6	2,283	6.0	12,416	1.6	454
5.4	1,966	6.8	4,738	5.8	2,665	6.5	13,941	1.8	544
5.5	2,131	7.0	5,250	6.0	2,965	7.0	15,525	2.0	642
5.6	2,304	7.2	5,793	6.5	3,780	7.5	17,160	2.2	748
5.7	2,484	7.4	6,365	7.0	4,695	8.0	18,845	2.4	862
5.8	2,672	7.6	6,969	7.5	5,708	8.5	20,577	2.6	984
5.9	2,867	7.8	7,605	8.0	6,810	9.0	22,351	2.8	1,114
6.0	3,070	8.0	8,270	8.5	7,998	9.5	24,165	3.0	1,252
6.2	3,490	8.5	10,059	9.0	9,270	10.0	26,012	3.2	1,398
6.4	3,910	9.0	12,030	9.5	10,620	10.5	27,887	3.4	1,552
6.6	4,330	9.5	14,180	10.0	12,045	11.0	29,787	3.6	1,714
6.8	4,750	10.0	16,510	10.5	13,536	11.5	31,712	3.8	1,884
7.0	5,170	10.5	19,015	11.0	15,036	12.0	33,653	4.0	2,061
7.2	5,590	11.0	21,690	12.0	18,036	.....	.....	4.5	2,533
7.4	6,010	11.5	24,536	13.0	21,036	.....	.....	5.0	3,052
7.6	6,430	12.0	27,550	14.0	24,036	.....	.....	5.5	3,613
7.8	6,850	.....	.....	.....	.....	.....	.....	6.0	4,217

NORTHERN PACIFIC COAST DRAINAGE.

In this division are included measurements on streams flowing into he Pacific north of the Columbia River. The river stations so far s established have been located within what is known as the Olymic Peninsula, the work being under the charge of Mr. W. J. Ware, f Port Angeles.

DESCRIPTION OF RIVER STATIONS.

Seattle station on Cedar River.—This station, described on pages 1-502 of the Nineteenth Annual Report, Part IV, was maintained Mr. T. A. Noble for the Seattle Power Company. A description the methods employed, with the results of discharge measureents, and diagrams, are published in an article by T. A. Noble, in e transactions of the American Society of Civil Engineers, Volume LI, June, 1899. The station was discontinued September 30, 1898, d observations begun at Vaughns Bridge, about 3,000 feet below the tlet of Cedar Lake, or 15 miles above the station at Cliffords Bridge.

Seguin station on Dungeness River.—Described on page 182 of per No. 16; results given on page 503 of the Nineteenth Annual port, Part IV. On July 29, 1898, the station was moved to a idge about 8½ miles downstream, this being about a mile above the outh. This bridge crosses the river diagonally, its northern end ing about 15 degrees upstream from a position perpendicular to the rrent. The initial point and bench mark is the inner edge or cor- r of the first post for the covering of bridge on the south end and st side of bridge. The rod is horizontal and the zero is 25.91 feet om the initial point; distance of pulley from zero on rod is 4.90 et; length of wire from end of ring to end of weight, 26.04 feet. he station was changed from the fact that measurements could be ken at the lower bridge much more accurately. At the upper idge there was a slough, and the water running through that could t be accounted for. Since the station has been moved Henry cAlmond has been observer.

McDonald station on Elwha River.—Described on page 183 of per No. 16; results for 1897 given on page 505 of the Nineteenth nual Report, Part IV.

Forks station on Calowa River.—Described on page 184 of Paper . 16. The observer, until August 25, 1898, was George W. Eaton; ce that date, Miss Irma Whittier, deputy postmaster at Forks.

Quillayute station on Solduck River.—Described on page 184 of per No. 16.

TABLES OF DAILY GAGE HEIGHT.

Daily discharge in cubic feet per second of Cedar River, near Seattle, Washington, for 1895.

Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.
1	.....	243	150	.....	18	174	163	163	836
2	.....	250	241	.....	19	178	165	155	788
3	.....	253	176	.....	20	217	161	128	735
4	.....	234	160	.....	21	200	157	174	695
5	.....	221	110	.....	22	206	153	155	669
6	.....	217	104	.....	23	200	152	144	855
7	.....	193	97	.....	24	356	152	138	802
8	.....	188	97	.....	25	433	166	125	786
9	.....	193	94	.....	26	382	152	125	731
10	.....	202	168	.....	27	337	152	236	1,355
11	.....	197	132	.....	28	315	146	241	1,355
12	.....	193	115	.....	29	291	148	152	1,329
13	182	186	115	2,176	30	262	144	180	.....
14	184	182	168	2,099	31	.....	138	.....	.....
15	188	178	165	1,687					
16	186	172	168	1,434	Mean	252	181	151	1,160
17	182	166	161	1,386					

Daily discharge in cubic feet per second of Cedar River, near Seattle, Washington for 1896.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1,023	766	1,766	786	1,191	2,002	1,901	315	202	170	745	757
2	892	743	1,381	768	1,265	1,675	1,371	347	197	178	784	1,172
3	828	751	1,256	743	1,163	1,434	1,329	228	195	190	920	2,165
4	828	758	1,079	721	1,144	1,363	1,308	330	193	188	836	3,601
5	1,355	1,228	845	715	1,116	1,371	1,265	320	188	180	790	3,623
6	1,867	1,265	811	684	1,181	1,410	1,219	313	182	170	764	3,396
7	2,034	1,320	792	659	1,107	1,426	1,237	306	180	.....	721	3,248
8	2,742	1,265	778	669	1,004	2,219	1,116	296	178	165	1,462	4,189
9	2,932	1,116	774	633	967	2,241	1,041	289	176	168	2,023	3,694
10	2,769	939	766	628	911	2,361	892	284	176	168	2,143	3,400
11	2,252	811	745	638	957	2,203	845	279	180	209	1,890	3,302
12	1,867	836	731	729	939	2,023	790	275	184	182	1,434	3,133
13	1,709	1,172	729	786	1,023	1,844	747	267	182	178	2,241	3,128
14	1,394	1,339	719	1,060	1,023	1,664	723	260	178	172	2,959	2,791
15	1,209	1,355	700	1,311	995	1,443	721	253	180	168	4,695	2,453
16	1,023	1,386	684	1,209	1,013	1,462	717	258	205	163	3,835	2,241
17	794	1,434	654	1,088	939	1,491	705	248	193	158	3,122	2,012
18	807	1,410	628	901	892	1,453	669	243	184	155	2,535	1,687
19	1,097	1,360	608	815	929	1,431	613	241	180	152	2,110	1,551
20	873	1,308	755	766	864	1,423	577	238	174	153	1,878	1,878
21	985	1,228	828	741	911	1,426	541	236	172	163	1,500	1,687
22	1,041	1,153	985	762	1,013	1,415	510	231	172	172	1,366	1,551
23	1,060	1,116	1,116	762	1,308	1,434	485	224	170	160	1,228	1,453
24	815	1,265	1,355	749	1,407	1,423	454	219	170	163	1,125	1,413
25	780	1,664	2,034	794	1,551	1,407	423	214	168	157	976	1,392
26	762	2,469	1,822	1,041	1,585	1,407	397	214	166	153	802	1,358
27	755	2,469	1,462	1,303	1,720	1,608	367	214	165	152	762	1,326
28	749	2,382	1,384	1,316	1,642	1,766	347	212	161	150	749	1,321
29	745	2,372	1,284	1,308	1,743	1,935	337	207	158	195	743	1,311
30	735	.....	1,032	1,237	1,901	1,732	340	202	157	212	723	1,265
31	727	.....	883	.....	2,029	.....	320	197	.....	221	.....	1,228
Mean	1,273	1,334	1,012	877	1,208	1,650	784	260	179	172	1,595	2,217

harge in cubic feet per second of Cedar River, near Seattle, Washington, for 1897.

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1,237	1,125	920	892	1,345	1,339	1,172	561	413	325	325	1,386
1,172	1,144	845	832	1,334	1,265	1,799	551	403	325	328	1,347
1,013	1,153	828	790	1,321	1,125	2,284	541	418	323	323	1,088
1,041	1,339	807	845	1,326	948	2,219	526	408	320	328	811
1,263	1,350	792	786	1,399	845	2,121	515	397	315	408	2,045
1,415	1,345	778	832	1,574	807	2,176	500	403	313	541	2,263
1,732	1,324	766	948	1,732	794	2,040	490	377	303	485	2,208
1,434	1,265	757	985	1,822	855	1,867	479	392	301	541	2,089
1,402	1,181	751	1,023	1,743	819	1,540	469	382	299	633	1,991
1,355	1,316	745	1,228	1,519	784	1,392	459	356	299	1,069	1,890
1,334	1,363	737	1,339	1,428	811	1,332	449	349	294	1,957	1,890
1,324	1,386	731	1,386	1,529	828	1,228	444	344	428	3,155	1,642
1,163	1,339	723	1,420	1,912	836	1,069	444	340	433	2,872	2,045
1,004	1,350	743	1,551	2,110	780	948	433	347	377	2,442	2,317
948	2,415	751	1,822	2,143	823	828	423	342	354	2,078	1,991
855	2,094	757	2,176	2,121	1,247	807	413	335	344	1,563	1,453
815	1,844	757	2,252	2,110	1,363	819	408	332	335	1,619	1,321
873	1,472	762	2,502	2,050	1,397	782	403	330	328	2,747	1,135
957	1,368	764	2,752	1,957	1,402	766	397	332	323	3,939	823
1,386	1,339	758	2,703	1,811	1,347	753	387	323	325	2,742	768
2,812	1,318	749	2,644	1,653	1,308	741	377	320	349	1,394	739
2,812	1,172	757	2,448	1,491	1,410	727	367	320	383	1,023	719
2,600	1,060	762	2,203	1,410	1,366	719	362	320	362	929	674
2,295	957	1,313	2,110	1,368	1,329	705	354	318	367	939	700
2,018	873	1,347	1,935	1,324	1,256	679	352	315	354	819	739
1,574	823	1,339	1,788	1,256	1,135	659	352	311	356	786	788
1,386	855	1,358	1,597	1,172	1,032	638	349	313	349	776	1,324
1,366	911	1,366	1,426	1,060	901	618	344	315	344	747	3,166
1,355	.....	1,316	1,386	939	828	597	344	320	337	695	3,601
1,345	.....	1,172	1,366	1,135	819	592	342	323	332	1,332	3,220
1,311	.....	976	.....	1,376	.....	572	362	.....	328	.....	2,622
1,440	1,303	901	1,509	1,562	1,060	1,135	427	350	340	1,318	1,639

harge in cubic feet per second of Cedar River, near Seattle, Washington, for 1898.

ay.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.
.....	2,214	449	731	474	1,004	780	510	152	.....
.....	1,844	397	735	454	920	751	474	165	.....
.....	1,415	423	751	438	957	770	449	168	.....
.....	1,363	423	760	413	1,144	741	423	165	.....
.....	1,324	721	729	397	1,284	766	397	160	.....
.....	1,097	1,957	757	423	1,191	774	372	138	.....
.....	1,004	1,529	760	526	1,097	1,004	352	152	.....
.....	1,004	1,380	751	561	957	1,097	344	149	.....
.....	864	1,376	721	551	828	1,191	323	143	95
.....	807	1,191	731	536	794	1,144	315	136	.....
.....	780	1,237	705	556	832	1,097	311	141	91
.....	764	1,337	679	546	929	1,004	299	145	.....
.....	731	1,263	679	613	864	911	291	.....	84
.....	577	2,459	705	654	939	807	284	.....	.....
.....	721	3,220	692	710	1,041	828	272	.....	78
.....	654	3,318	551	715	1,191	794	255	.....	.....
.....	679	2,785	474	723	1,350	780	274	.....	73
.....	654	2,323	449	731	1,363	751	291	.....	.....
.....	731	2,050	423	710	1,324	760	265	.....	71
.....	741	1,402	526	679	1,191	770	255	.....	.....
.....	751	1,368	500	654	1,004	760	243	.....	117
.....	731	1,004	449	735	911	751	236	.....	.....
.....	679	1,004	423	753	864	731	226	.....	207
.....	628	864	449	770	807	705	219	.....	.....
.....	602	760	449	828	790	679	207	.....	184
.....	551	751	423	1,116	864	669	200	.....	.....
.....	551	721	408	1,350	883	654	188	.....	214
.....	526	745	433	1,337	1,004	577	184	.....	.....
.....	500	.....	449	1,284	976	526	178	.....	219
.....	449	.....	510	1,237	855	485	172	.....	.....
.....	423	.....	474	.....	790	.....	165	.....	.....
.....	850	1,377	587	716	998	802	289	151	130

Daily gage height, in feet, of Dungeness River at Seguin, Washington, for 1893.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.80	4.30	4.80	4.30	5.00	5.20	5.10	4.00	3.05	2.70	2.75	2.55
2	4.80	4.30	4.80	4.30	5.10	5.20	5.30	4.00	3.00	2.75	2.75	2.55
3	4.75	4.30	4.90	4.30	5.15	5.00	5.40	4.00	3.00	2.70	2.80	2.50
4	4.70	4.30	4.90	4.30	5.30	5.00	5.40	3.85	2.90	2.70	2.80	2.50
5	4.70	5.20	4.80	4.35	5.30	5.30	5.30	3.75	2.80	2.65	2.80	2.50
6	4.70	5.30	4.80	4.50	5.20	5.40	5.20	3.80	2.80	2.60	2.85	2.45
7	4.70	5.50	4.70	4.50	5.00	5.60	5.00	3.85	2.75	2.45	2.85	2.45
8	4.70	5.10	4.65	4.40	5.00	5.70	5.00	3.90	2.75	2.40	2.80	2.45
9	4.60	4.90	4.65	4.50	5.00	5.60	5.20	3.85	2.80	2.60	2.75	2.45
10	4.50	4.80	4.60	4.50	5.30	5.60	5.20	3.85	2.80	2.60	2.70	2.40
11	4.50	4.80	4.60	4.40	5.40	5.60	5.25	3.85	2.85	2.60	2.65	2.35
12	4.50	5.00	4.55	4.50	5.20	5.50	5.30	3.85	2.85	2.60	2.60	2.35
13	4.50	5.20	4.50	4.75	5.20	5.50	5.20	3.55	2.85	2.60	2.60	2.35
14	4.50	5.40	4.50	4.80	5.30	5.50	5.20	3.50	2.85	4.70	2.55	2.30
15	4.45	5.55	4.45	4.75	5.50	5.55	5.20	3.45	2.85	4.20	2.60	2.30
16	4.45	5.40	4.40	4.70	5.60	5.50	5.20	3.40	2.80	3.50	2.70	2.30
17	4.45	5.20	4.40	4.70	5.70	5.40	5.10	3.30	2.85	3.40	2.65	2.30
18	4.45	5.00	4.30	4.60	5.45	6.30	5.10	3.35	2.85	3.30	2.60	2.30
19	4.40	4.90	4.30	4.60	5.30	5.00	5.00	3.35	3.00	3.20	2.55	3.50
20	4.40	5.00	4.30	4.65	5.20	5.40	5.00	3.35	3.20	3.15	2.55	2.90
21	4.40	4.90	4.30	4.60	5.40	5.40	5.00	3.30	3.30	3.05	2.50	2.85
22	4.35	4.80	4.30	4.60	5.20	5.35	5.00	3.30	4.05	2.95	2.50	2.80
23	4.35	4.80	4.30	4.65	5.00	5.35	5.00	3.30	3.40	2.90	2.50	2.70
24	4.35	4.75	4.30	4.70	5.00	5.40	5.00	3.30	3.00	2.85	2.55	2.60
25	4.35	4.80	4.30	5.00	4.95	5.40	5.00	3.30	2.90	2.80	2.55	2.70
26	4.35	4.75	4.30	5.20	5.40	5.35	5.00	3.30	2.90	2.80	2.55	3.30
27	4.35	4.75	4.25	4.50	5.40	5.30	5.00	3.30	2.95	2.75	2.60	4.35
28	4.30	4.80	4.20	5.00	5.20	5.20	5.00	3.20	2.90	2.70	2.60	5.20
29	4.30	.....	4.20	5.00	5.20	5.20	4.05	3.15	2.85	2.70	2.60	4.45
30	4.30	.....	4.30	4.95	5.20	5.15	4.05	3.15	2.75	2.70	2.60	3.90
31	4.30	.....	4.30	.....	5.20	.....	4.15	3.10	.....	2.70	.....	3.70

Daily gage height, in feet, of Elwha River at McDonald, Washington, for 1893.

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.80	1.90	2.58	1.60	2.55	2.74	3.20	2.25	1.54	1.66	2.44	2.00
2	3.65	1.85	2.57	1.62	2.52	2.66	3.20	2.35	1.54	1.51	2.62	1.92
3	3.52	1.99	2.46	1.65	2.53	2.54	3.41	2.50	1.49	1.40	2.22	1.81
4	3.33	1.93	2.85	1.66	3.15	2.68	3.15	2.47	1.42	1.42	2.23	1.75
5	3.20	4.44	2.80	1.70	3.10	3.02	2.61	2.41	1.39	1.40	2.22	1.75
6	3.20	4.38	2.49	1.72	3.07	3.56	2.54	2.36	1.38	1.40	2.21	1.62
7	3.18	4.45	2.41	1.95	3.01	3.70	2.50	2.30	1.45	1.31	2.12	1.52
8	3.18	4.42	2.35	1.99	2.10	3.91	2.52	2.25	1.46	1.29	1.80	1.52
9	2.61	3.00	2.32	2.48	2.58	4.01	2.60	2.45	1.49	1.26	1.81	1.51
10	2.37	2.96	2.26	2.39	3.00	4.06	2.65	2.47	1.47	1.20	1.78	1.51
11	2.60	4.12	2.15	1.91	2.90	3.68	2.75	2.46	1.47	1.22	1.70	1.47
12	2.32	3.97	2.39	1.88	3.21	3.52	3.18	2.19	1.48	1.35	1.67	1.46
13	2.22	4.26	2.33	2.10	3.00	3.50	2.85	2.17	1.45	3.50	1.64	1.45
14	2.19	4.15	2.29	2.15	3.01	3.42	2.78	2.15	1.42	4.50	1.62	1.46
15	2.20	5.12	2.15	2.17	3.58	3.40	2.65	2.12	1.40	3.10	1.60	1.48
16	2.16	4.91	2.10	2.16	3.78	4.04	2.61	1.98	1.43	2.40	1.75	1.54
17	2.13	3.59	2.02	2.15	3.97	3.74	3.60	1.90	1.44	2.31	1.80	1.59
18	2.20	3.45	1.95	2.00	3.40	4.10	3.10	1.90	1.44	2.10	2.10	1.64
19	2.65	3.17	1.99	1.90	3.31	5.15	2.90	1.87	1.47	2.00	1.98	2.82
20	2.61	3.40	2.00	1.85	2.99	3.80	2.30	1.97	1.63	1.90	1.78	2.45
21	2.60	3.20	1.90	1.80	3.54	3.33	2.15	1.94	2.47	1.90	1.78	1.99
22	2.26	3.15	1.85	2.28	2.15	3.20	2.90	1.92	3.18	1.87	1.77	1.96
23	2.10	3.00	2.00	2.22	2.80	3.15	2.30	1.90	2.12	1.70	1.70	1.92
24	2.08	2.70	1.95	2.24	2.60	3.02	2.35	1.87	1.95	1.65	1.70	1.90
25	1.90	2.60	1.85	3.25	3.84	3.05	2.45	1.90	1.52	1.56	1.79	1.95
26	1.80	2.55	1.80	2.61	3.55	3.00	2.41	1.84	1.43	1.57	1.72	5.20
27	1.75	2.58	1.74	2.52	3.60	3.10	2.40	1.83	1.39	1.59	2.20	4.95
28	1.78	2.60	1.69	2.45	3.50	2.98	2.35	1.58	1.45	1.62	2.24	4.70
29	2.00	.....	1.65	2.60	3.05	2.97	2.55	1.84	2.03	1.60	2.12	4.30
30	2.04	.....	1.65	2.62	2.95	2.92	2.60	1.82	1.69	1.71	2.50	3.18
31	1.90	.....	1.60	.....	2.76	.....	2.65	1.55	.....	1.68	.....	3.15

Daily gage height, in feet, of Calowa River at Forks, Washington, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.55	2.15	3.60	1.50	1.50	1.65	1.15	0.35	— .10	1.30	4.00	6.05
2	3.10	2.35	3.00	1.45	1.80	1.45	1.05	.30	— .10	1.05	3.40	5.85
3	3.25	2.60	3.85	1.25	1.05	1.15	1.02	1.50	— .10	1.04	5.80	3.65
4	2.90	2.85	3.40	1.10	1.20	.85	1.03	1.10	— .10	1.05	5.00	3.45
5	3.20	9.60	3.00	.80	1.35	1.35	1.00	1.11	— .10	1.00	4.30	3.00
6	3.20	7.80	2.75	.65	1.30	1.15	1.06	1.90	— .10	.90	4.40	2.85
7	3.00	7.65	2.40	1.65	1.15	.95	1.50	.50	— .10	.90	3.45	2.60
8	3.35	5.00	2.25	2.35	1.00	.80	1.20	.15	— .10	.80	3.05	2.40
9	3.00	5.25	2.35	5.30	1.45	.75	1.30	.14	— .10	1.00	2.75	2.25
10	2.70	5.85	1.80	4.25	1.30	.70	.30	.10	— .10	1.00	2.45	2.10
11	2.50	6.00	1.65	3.25	1.25	.65	.10	.13	— .10	1.60	2.20	1.90
12	2.35	6.75	2.35	2.65	1.10	.55	.20	.15	— .10	1.80	2.00	1.65
13	2.50	5.35	2.00	2.10	.90	.60	.10	.12	— .20	5.80	1.80	1.70
14	2.55	6.55	1.80	1.75	.85	.55	.10	.....	— .20	5.35	1.60	1.75
15	2.60	9.00	1.50	1.25	.80	.70	.20	.....	— .40	3.60	1.60	1.80
16	2.70	5.45	1.45	1.45	.70	1.10	.40	.....	— .40	2.70	1.60	1.85
17	2.80	4.35	1.30	1.85	.65	1.35	2.40	.....	— .40	2.45	3.00	1.60
18	3.45	3.80	1.25	1.60	.70	1.50	1.20	.....	— .40	2.20	3.25	1.60
19	5.50	3.35	1.20	1.35	.65	3.55	1.00	.....	— .40	1.85	1.80	5.40
20	5.15	3.10	1.75	1.15	.55	2.60	.80	.....	+2.00	1.80	2.65	4.00
21	3.90	4.40	1.45	1.50	.80	2.15	.60	.....	3.20	1.60	2.70	3.60
22	3.75	4.10	1.30	2.70	1.50	1.90	.30	.....	2.80	1.40	3.00	3.70
23	3.25	3.70	1.50	2.35	1.35	1.55	.10	.....	2.15	1.20	3.85	3.20
24	3.00	3.00	2.35	1.95	1.10	1.70	.45	.....	2.00	1.10	2.85	2.85
25	2.70	3.35	1.70	2.85	.90	1.60	.30	.....	1.40	1.00	3.00	4.85
26	2.00	2.60	1.40	3.10	1.35	1.35	.50	.00	1.00	2.05	3.05	7.90
27	1.85	3.85	1.35	2.65	1.20	1.60	.35	.00	1.20	2.40	4.60	9.20
28	2.00	4.50	1.85	2.25	1.15	1.35	.40	.00	1.80	2.20	4.85	8.00
29	2.30	.....	1.50	1.85	1.65	1.30	.55	—.10	2.20	1.80	5.10	7.20
30	2.55	.....	1.35	1.40	1.50	1.20	.35	.00	2.05	2.00	5.35	6.15
31	2.30	.....	1.20	.....	1.45	.....	.45	—.10	.....	2.00	.....	3.00

Daily gage height, in feet, of Solduck River at Quillayute, Washington, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.90	2.80	3.95	2.45	2.60	2.25	2.25	1.55	1.10	2.45	2.90	5.45
2	4.75	2.70	3.90	2.40	2.55	2.20	2.30	1.50	1.10	2.35	4.10	4.85
3	4.60	2.80	4.30	2.35	2.75	2.20	2.25	1.55	1.05	2.15	5.55	4.35
4	4.25	2.90	4.20	2.35	2.95	2.15	2.20	1.50	1.05	2.05	4.80	4.05
5	4.20	3.75	3.90	2.30	2.80	2.25	2.20	1.45	1.05	1.90	4.60	3.70
6	4.10	6.65	3.60	2.30	2.75	2.35	2.15	1.45	1.05	1.80	4.50	3.55
7	3.90	7.70	3.45	2.40	2.65	2.60	2.10	1.40	1.05	1.70	4.35	3.40
8	4.05	5.75	3.25	2.50	2.50	2.55	2.00	1.40	.95	1.65	3.80	3.25
9	3.75	5.60	3.15	3.95	2.50	2.60	1.95	1.40	.95	1.75	3.45	3.15
10	3.60	5.05	3.05	4.05	2.45	2.65	1.95	1.35	1.00	1.70	3.30	3.10
11	3.50	5.20	2.90	3.45	2.65	2.50	1.95	1.35	.95	2.15	3.10	3.00
12	3.30	6.50	2.95	3.20	2.60	2.40	2.00	1.35	.95	2.55	2.95	2.90
13	3.35	5.70	2.85	3.20	2.50	2.30	2.00	1.35	1.00	3.25	2.80	2.80
14	3.35	6.95	2.80	3.15	2.45	2.35	1.90	1.30	.95	7.45	2.65	2.65
15	3.30	7.40	2.70	3.05	2.60	2.60	1.85	1.25	.95	5.05	2.70	2.70
16	3.25	6.60	2.60	2.90	2.70	2.85	1.90	1.25	.95	3.80	2.90	2.75
17	3.40	5.55	2.50	2.75	2.70	2.50	2.30	1.25	.95	3.45	3.25	2.85
18	3.65	5.20	2.45	2.60	2.75	2.50	2.50	1.25	.95	3.30	4.10	2.80
19	4.50	4.60	2.40	2.50	2.55	3.90	2.30	1.35	1.00	3.10	3.80	5.55
20	4.35	5.80	2.50	2.40	2.70	3.20	1.95	1.30	1.15	2.90	3.55	4.80
21	3.90	5.20	2.40	2.45	2.75	2.85	1.90	1.30	2.05	2.75	3.45	4.25
22	3.95	4.80	2.40	2.80	3.00	2.70	1.80	1.30	2.60	2.60	3.95	4.10
23	3.60	4.60	2.30	2.75	2.70	2.65	1.70	1.25	3.05	2.45	4.05	3.75
24	3.40	4.35	2.65	2.70	2.40	2.65	1.65	1.25	2.40	2.30	3.80	3.55
25	3.25	4.35	2.50	3.20	2.50	2.70	1.65	1.20	1.90	2.25	3.50	3.70
26	3.25	4.25	2.35	3.25	2.55	2.50	1.60	1.20	1.70	2.45	3.75	6.35
27	3.10	4.00	2.50	3.30	2.65	2.40	1.65	1.15	1.60	2.70	4.05	6.85
28	3.05	4.05	2.65	3.10	2.50	2.35	1.60	1.15	1.55	2.80	4.35	7.30
29	2.90	.....	2.60	2.90	2.45	2.30	1.55	1.15	1.95	2.65	4.75	5.50
30	3.10	.....	2.55	2.75	2.40	2.25	1.60	1.15	2.85	2.50	5.10	4.70
31	2.95	.....	2.45	.....	2.30	.....	1.55	1.15	.....	2.65	.....	4.45

List of discharge measurements, 1898.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
				Feet.	*Sec.-feet.*
Jan. 18	Dungeness River	Seguin, Wash	A. J. Adams	4.45	347
Mar. 3	do	do	do		68
June 25	do	do	do	5.50	617
July 28	do	do	William J. Ware	5.10	336
July 29	do	do	do	4.65	327
Sept. 17	do	do	do	3.30	18
Oct. 15	do	do	do	4.00	43
Nov. 29	do	do	do	2.60	13
Dec. 24	do	do	do	2.60	13
Jan. 30	Elwha River	McDonald, Wash	A. J. Adams	1.74	1,098
Mar. 7	do	do	do	2.45	1,553
June 29	do	do	do	3.80	2,467
July 2	do	do	do	3.20	2,182
Aug. 29	do	do	William J. Ware	1.80	768
Oct. 25	do	do	do	1.56	537
Nov. 8	do	do	do	1.80	857
Dec. 9	do	do	do	1.51	622
June 30	Calowa River	Forks, Wash	A. J. Adams	1.20	467
Aug. 26	do	do	William J. Ware	.00	131
Dec. 19	do	do	do	5.40	3,294
June 29	Soldnck River	Quillayute, Wash	A. J. Adams	2.25	823
Aug. 27	do	do	William J. Ware	1.15	289
Dec. 19	do	do	do	5.55	3,160

Rating tables.

Seguin. *a*		Seguin. *b*		Seguin. *c*		McDonald.		Forks.		Quillayute.	
Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage h'g't.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
4.0	110	4.0	213	2.6	155	1.0	250	−0.4	40	1.0	220
4.1	125	4.1	220	2.7	156	1.1	290	−.2	80	1.2	312
4.2	138	4.2	227	2.8	157	1.2	330	.0	130	1.4	404
4.3	157	4.3	234	2.9	161	1.3	400	.2	180	1.6	500
4.4	177	4.4	241	3.0	165	1.4	470	.4	230	1.8	600
4.5	203	4.5	248	3.1	170	1.5	575	.6	286	2.0	700
4.6	234	4.6	255	3.2	175	1.6	687	.8	348	2.2	810
4.7	285	4.7	262	3.3	183	1.7	799	1.0	410	2.4	920
4.8	361	4.8	273	3.4	194	1.8	911	1.2	474	2.6	1,035
4.9	438	4.9	288	3.5	211	1.9	1,025	1.4	538	2.8	1,155
5.0	515	5.0	310	3.6	233	2.0	1,150	1.6	604	3.0	1,275
5.1	592	5.1	336	3.7	260	2.2	1,337	1.8	672	3.2	1,397
5.2	669	5.2	406	3.8	295	2.4	1,525	2.0	740	3.4	1,519
5.3	746	5.3	476	3.9	330	2.6	1,675	2.2	816	3.6	1,644
5.4	823	5.4	546	4.0	365	2.8	1,825	2.4	892	3.8	1,772
5.5	900	5.5	617	4.1	400	3.0	1,975	2.6	974	4.0	1,900
5.6	979	5.6	687	4.2	435	3.2	2,113	2.8	1,062	4.2	2,046
5.7	1,058	5.7	757	4.3	470	3.4	2,251	3.0	1,150	4.4	2,192
5.8	1,137	5.8	827	4.4	505	3.6	2,383	3.2	1,254	4.6	2,346
5.9	1,216	5.9	897	4.5	540	3.8	2,509	3.4	1,358	4.8	2,508
6.0	1,295	6.0	967	4.6	575	4.0	2,635	3.6	1,472	5.0	2,670
6.2	1,453	6.1	1,037	4.7	610	4.2	2,748	3.8	1,596	5.2	2,846
6.4	1,611	6.2	1,107	4.8	645	4.4	2,861	4.0	1,720	5.4	3,022
6.6	1,769	6.3	1,177	4.9	680	4.6	2,974	4.5	2,110	5.6	3,214
6.8	1,927	6.4	1,247	5.0	715	4.8	3,087	5.0	2,620	5.8	3,422
7.0	2,085	6.5	1,317			5.0	3,200	5.5	3,400	6.0	3,630
7.2	2,243					6.0	3,750	6.0	4,080	6.2	3,838
7.4	2,401					7.0	4,220	7.0	5,440	6.4	4,046
7.6	2,559					8.0	4,625	8.0	6,800	6.6	4,254
7.8	2,717							9.0	8,160	6.8	4,462

a Applicable from July 5 to December 31, 1897.
b Applicable from January 1 to July 28, 1898.
c Applicable from July 29 to December 31, 1898.

SAN FRANCISCO BAY DRAINAGE.

DESCRIPTION OF RIVER STATIONS.

Jelleys Ferry station on Sacramento River.—Described on page 185 ıf Paper No. 16; results for 1897 given on page 509 of the Nineteenth ınnual Report, Part IV. During the year 1898 Mr. Fred Lemstrom as been furnished with a meter and has made at least two measure- ıents a month of the river, or as often as any radical change occurred ı the volume of the stream. He was furnished with Price's acoustic ıeter No. 12, which he used until the 1st of June. This was the only ıeter available during the first portion of the year for this work; sub- ;quent to the 1st of June he was furnished with a large Price electric ıeter (No. 67). Observations with the acoustic meter were made, here practicable, at six-tenths depth, to determine the mean velocity f the stream; because of the depth of the river this could not always e done. With the larger meter top, middle, and bottom velocity are lways taken. As previously described, the discharge measurements re made from a boat held by the cable. The rating curve for the ear 1898 indicates that the river is deepening its bed. A rapid ccurs about one-half mile below the gaging station. Observations 'ere taken of river heights twice each day throughout the year. The ischarge measurements, shown on page 185, were made in 1898 by 'red Lemstrom.

Oakdale station on Stanislaus River.—Described on page 187 of 'aper No. 16, and also on page 510 of the Nineteenth Annual Report, 'art IV; was located until July 30, 1898, at the wagon bridge one-half ıile north of the town of Oakdale, California. One gage rod is set etween the south or left-hand piers of the wagon bridge on the side ›ward the water, and can be read from the bridge. The datum is 7.92 feet below the top of the southeast iron pier of the wagon bridge. . rod for lowest readings of the river is 125 feet below the wagon ridge on the left bank and referred to the same datum. A second- :y gage for determining the slope of the river is attached to the 'ib abutment of the Southern Pacific railroad bridge, 1,071 feet ›low the wagon bridge and referred to the same datum as the ›per gage. Its zero is 5.92 feet below the top of the cap on the piles the south crib pier of the railroad bridge. The pier has settled ıring the last year. The channel of the river is uniform and raight above and below the station, and both banks are high ough to prevent overflow in all except extreme conditions of flood. ıe bed of the stream at this point is of sand and gravel and changes ıly slightly.

The observer until May 4 was Walter Beistle; since then J. W. Bell ıs been observing on the river, and has reported the daily water ›ight of the river at this point. Soundings were taken twice ch month to determine the area of the cross section of the

stream, the intention being to determine the relation between the discharge in volume and area of cross section of the stream, and to use these elements in case the relation between the height of water on gage rod and volume discharged was not satisfactory. The point from which the measurements were made up to July, 1898, was the wagon bridge, 1,071 feet above the railroad bridge. This wagon bridge is nearly 60 feet above the surface of the water, consequently measurements were not as satisfactory as desired. On July 30, 1898, a cable was stretched across the river, 1,000 feet below the railroad bridge, at J. W. Bell's ranch house. The section at this point is relatively satisfactory, there being a stretch of straight river for 1,000 feet above and below the cable. Sand bars, however, are a constant objection to all points on the river, shifting their position with the changing seasons. In order to have the gage rod near the house of Mr. Bell, who is the observer, and also because of contemplated repairs on the railroad bridge to which the old gage was attached, on July 30, 1898, the gage was moved from the south pier of the railroad bridge to a point on the left bank of the stream, 250 feet above the cable and at the side of Mr. Bell's peach orchard; subsequent to this date all observations were taken on this gage. Two rating tables are therefore given for this stream, one prior and one subsequent to July 30, 1898.

As has been stated in previous reports, there are many diversions on the Stanislaus River above Oakdale, the principal one of which is by the Stanislaus and San Joaquin Valley Water Company. The water of the river is diverted on the right bank by this company, in a flume at a point 3 miles above Knights Ferry. A straight section of the flume, known as section 3, was selected, and by turning into it varying amounts of water a complete rating was obtained on June 1, 1898. Mr. J. Y. Beveridge, of Knights Ferry, California, who is the superintendent of the canal, has very kindly furnished the Geological Survey, since the 1st of June, with the daily depth of the water in the canal, from which the volume has been determined. A peculiarity about the rating table for this canal is that the gage height given is the distance down from a fixed point to the water surface. The water carries so much silt from the gold stamp mills above that a gage rod becomes quickly covered with slime, preventing an accurate reading of it. In the column marked "Gage heights," the less the difference given the greater is the corresponding discharge. The rating table for the Stanislaus River indicates that the bed is filling and rising, which is what might have been anticipated, because of the large gold-mining operations which are being carried on above. The discharge measurements, given on page 185, were made in 1898 by J. B. Lippincott.

Lagrange station on Tuolumne River.—Described on page 188 of Paper No. 16; results for 1897 on page 512 of the Nineteenth Annual

Report, Part IV; is located at the bridge in the town of Lagrange, California, 32 miles from Modesto. Observations have been taken daily on the vertical gage rod, which is fastened to timbers between the two iron piers on the right bank of the river. The bench mark is a nail driven into the bottom of the west post of the fifth bent south of the south iron cylinder, and is 15.31 feet above the zero of the rod. The channel, both above and below the bridge, is straight for several hundred feet, and the velocity of the stream is quite uniform. Both banks are high and not subject to overflow. The bed is of gravel. The observer was Cleo Pereira until June 11, and has been Anna P. McGinn for the balance of the year. During the past year the Lagrange Ditch and Hydraulic Mining Company's Canal, which is commonly known as the Mining Company's Canal, which diverts water from the left bank 3 miles above the Lagrange dam, has continued carrying water to its full capacity throughout the year. This volume is approximately 1,200 miner's inches or 24 second-feet. Water from this canal is used for ground sluice mining on the left bank of the river. About one-fourth of this amount returns to the river above the bridge, the rest returning below the bridge. In the latter portion of the year the Turlock irrigation district succeeded in running a small volume of water through its irrigation canal, which diverts its supply from the left bank of the stream at the Lagrange Dam. The amount of this water has been very small, and has been used solely for puddling the banks of the canal and for testing the dams at certain reservoirs. The rating curve for this stream has remained the same for the year 1898 as for 1897. The list of discharge measurements, made by J. B. Lippincott, is given on page 185.

Modesto station on Tuolumne River.—Described on page 189 of Paper No. 16; is located one-half mile south of the depot and at the wagon-road bridge at Modesto, California. The observer is J. T. Reed. Daily observations of river heights have been obtained through the courtesy of William Hood, chief engineer of the Southern Pacific Company. They extend only to January 18, at which time the gage was removed and the station discontinued. This station was not satisfactory in establishing the relation between the volumes discharged and the height of water on the gage rod. Daily records of volume are kept at Lagrange, which is on the same stream 32 miles above, and therefore no measurements of volumes were taken at the Modesto station during the past year.

Herndon station on San Joaquin River.—Described on page 190 of Paper No. 16; results for 1897 given on page 514 of the Nineteenth Annual Report, Part IV; located at the wagon bridge about one-half mile north of Herndon and 12 miles north of Fresno, California, on the line of the Southern Pacific Company. The original gage consisted of a vertical rod fastened to the lower side of the south central railroad bridge pier. The water of this stream attacks the paint on the gage

rod to a peculiar extent. To avoid this inconvenience a new rod was placed above the old one and nailed to the upper portion of the bridge. A float acting in a box, by means of a copper wire passing over a roller, actuates an index which points to a gage height corresponding to the datum of the original rod. The bench mark is at the south end of the wagon-bridge trestle, on the west side, on a nail in a post, 0.2 of a foot above the ground, and marked by a B. M. cut in the post. This elevation shows the rod datum is 24.12 feet. A gage on the same datum is also painted on the southwest cylinder. The channel for 900 feet above and 3,000 feet below the bridge is straight and the water has a uniform velocity. The right bank is high, rocky, and steep. The bed of the stream is sandy and gravelly. The observer is G. G. Nelson. Daily observations of river heights have been made at this station throughout the year, and in addition soundings have been taken twice a month to determine the varying areas of cross section of the river. The station for the years 1896 and 1897 was peculiarly satisfactory, but during the year 1898 it has proved erratic. Measurements of volume during the past season indicate that a different rating curve should be used for 1898 than that used in 1897. The measurements taken during the year 1898 agree quite well within themselves, but differ from previous ones. An effort has been made in this case to establish the relation between areas of cross section and volumes discharged. The condition described above may be explained by the forming of sand bars below the gaging station. The rating curve indicates that the bed of the stream is rising. The discharge measurements, given on page 185, were made by J. B. Lippincott.

Red Mountain station on Kings River.—Described on page 191 of Paper No. 16; results for 1897 given on page 518 of the Nineteenth Annual Report, Part IV; located 15 miles east of Sanger, California, southwest of Red Mountain. The station is on what is called the "Lower section of No. 9" of the lumber flume. It is located at the mouth of the Kings River Canyon and above all diversions from the stream. Within a distance of 5 miles below this station the following canals are taken out: On the right bank, the Church Ditch, which has the prior right; the Fowler Switch Canal, and the Kingsburg Canal; and on the left bank the 76 Canal. The bed of the stream is of gravel and bowlders, and it has maintained its section well since the time it was established in 1896. Measurements made during the year 1898 indicate that the rating curve has not changed materially; a slight correction is made in it between the gage heights 6½ feet and 9½ feet. Daily observations of river heights have been taken throughout the past year by Mrs. Alice House, except during a period from September 18 to October 1, for which time values have been estimated. The discharge measurements, given on page 185, were made by J. B. Lippincott.

Kingsburg station on Kings River.—Described on page 192 of Paper

). 16; results for 1897 given on page 520 of the Nineteenth Annual port, Part IV; located on the Southern Pacific Company's bridge, proximately 1 mile south of Kingsburg, California. The water is ep and slow. The observer is Alf. Thompson, and daily gage heights ring the past year have been furnished through the courtesy of illiam Hood, chief engineer of the Southern Pacific Company. e repeated efforts to establish some relation between heights of ter on the gage and volumes discharged or areas of cross section to lumes discharged has failed. An investigation was made which owed that diversions from the river, which are made at a point out 2 miles below the gaging station, through certain head gates, aterially affect the grade and section of the river at the railroad idge. For these reasons it has been considered advisable to dis- ntinue the effort to give daily tables of volumes discharged and to ve only the heights of water on the gage and the individual meas- ements that have been made. The station is of interest and impor- nce, owing to the extensive litigation over the waters of the stream, e principal diversions from it occurring above the gaging station, d also to the fact that return water from the San Joaquin Valley is ginning to manifest itself in the increased volume of this river tween the upper and lower diversions.

As previously stated, the channel of the stream at this station is dly broken by the piers of the railroad bridge and of a wagon idge which is immediately below. Because the section is so poor at is point, measurements of discharge have been taken during 1898 at point known as "Clarks Bridge," which is approximately 2 miles ove the railroad bridge and crosses with a single span. The water Clarks Bridge is deep and in the low stages of the stream it has a ry slow velocity. During the summer of 1898 this velocity has been slow that the meter would not act, consequently the stream has en gaged at a point a short distance above the railroad bridge, here the observations of the meter were taken by wading. The rod adings corresponding with the measurements that were taken both the Kingsburg railroad bridge, at Clarks Bridge, and at the inter- ediate station where wading occurred, all were taken at the Kings- rg railroad bridge. This station was considered of value because the series of diversions of the water a short distance below for the igation districts around Hanford. As stated above, there is a con- lerable amount of return water in this Kings River, which in part pplied this lower demand.

"*First point of measurement*" *station on the Kern River.*—Contin- us observations by means of an automatic recording apparatus ve been maintained on this stream by the Kern County Land Com- ny, and in addition measurements of volumes discharged have been de once a week by this company. These records have been fur- shed by the courtesy of Mr. Walter James, chief engineer.

TABLES OF DAILY GAGE HEIGHT.

Daily gage height, in feet, of Sacramento River at Jellys Ferry, California, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	5.90	5.70	11.50	6.00	5.90	7.30	5.40	5.10	5.00	5.10	5.10	5.55
2	5.90	5.80	10.00	6.00	5.90	7.50	5.40	5.10	5.00	5.10	5.10	5.40
3	5.90	5.80	9.10	6.00	5.80	7.10	5.30	5.10	5.00	5.30	5.20	5.35
4	5.90	6.00	8.70	6.00	5.80	7.00	5.30	5.00	5.00	5.30	5.20	5.30
5	5.90	6.10	8.30	6.00	5.80	6.70	5.30	5.00	5.00	5.30	5.20	5.30
6	5.95	8.10	8.10	6.05	5.70	6.60	5.30	5.00	5.00	5.30	5.10	5.30
7	6.00	11.50	7.80	6.30	5.60	6.40	5.30	5.00	5.00	5.20	5.10	5.30
8	6.00	12.10	7.70	6.20	5.60	6.30	5.30	5.00	5.00	5.20	5.10	5.20
9	6.00	9.30	7.60	6.20	5.50	6.20	5.30	5.00	5.00	5.20	5.10	5.20
10	5.90	8.40	7.50	6.20	5.50	6.10	5.20	5.00	5.00	5.20	5.10	5.20
11	5.80	8.10	7.30	6.20	5.50	6.10	5.20	5.00	5.00	5.20	5.10	5.20
12	5.80	7.80	7.30	6.10	5.50	6.00	5.20	5.00	5.00	5.10	5.10	5.20
13	5.80	7.50	6.90	6.10	5.50	5.90	5.20	5.00	5.00	5.10	5.10	5.20
14	5.80	7.40	6.90	6.20	5.50	5.90	5.20	5.00	5.00	5.10	5.10	5.25
15	5.80	7.30	6.80	6.30	5.60	5.90	5.20	5.00	5.00	5.10	5.10	5.30
16	5.80	7.40	6.70	6.30	5.80	5.80	5.20	5.00	5.00	5.10	5.10	5.30
17	5.80	7.30	6.60	6.30	5.90	5.80	5.20	5.00	5.00	5.10	5.10	5.30
18	5.80	7.00	6.60	6.30	6.10	5.80	5.20	5.00	5.00	5.10	5.10	5.30
19	5.80	7.00	6.60	6.20	6.00	5.80	5.20	5.00	5.00	5.10	5.30	5.40
20	5.80	6.70	6.50	6.15	5.90	5.70	5.20	5.00	5.00	5.10	5.40	5.75
21	5.80	8.00	6.40	6.15	6.00	5.70	5.10	5.00	5.00	5.10	5.30	5.65
22	5.80	7.30	6.40	6.10	7.60	5.60	5.10	5.00	5.00	5.10	5.30	5.45
23	5.80	7.00	6.30	6.10	6.60	5.60	5.10	5.00	5.00	5.20	5.30	5.40
24	5.80	7.90	6.30	6.10	6.20	5.60	5.10	5.00	5.00	5.30	5.30	5.30
25	5.80	9.70	6.20	6.10	6.20	5.50	5.10	5.00	5.00	5.30	5.20	5.30
26	5.70	8.00	6.20	6.30	6.10	5.50	5.10	5.00	5.00	5.30	5.20	5.30
27	5.70	11.10	6.20	6.20	6.00	5.50	5.10	5.00	5.10	5.20	5.20	5.30
28	5.70	15.20	6.10	6.10	7.60	5.50	5.10	5.00	5.10	5.15	5.35	5.30
29	5.70	.....	6.10	6.00	7.00	5.40	5.10	5.00	5.10	5.10	6.00	5.30
30	5.70	.....	6.10	6.00	6.60	5.40	5.10	5.00	5.10	5.10	6.15	5.30
31	5.70	.....	6.00	.....	6.40	.....	5.10	5.00	.....	5.10	.....	5.30

Daily gage height, in feet, of Stanislaus River at Oakdale, California, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.50	2.50	3.90	3.10	5.60	3.60	2.80	4.30	4.30	4.30	4.30	4.60
2	2.60	2.40	3.80	3.20	5.10	3.60	2.80	4.40	4.30	4.30	4.30	4.60
3	2.50	2.40	3.70	3.20	4.30	3.30	2.70	4.40	4.30	4.40	4.30	4.50
4	2.70	2.30	3.60	3.20	4.30	3.20	2.50	4.40	4.30	4.30	4.30	4.50
5	2.50	2.30	3.50	3.10	4.10	3.20	2.50	4.30	4.20	4.30	4.30	4.50
6	2.60	2.40	3.50	3.20	4.20	3.50	2.50	4.30	4.20	4.30	4.30	4.50
7	2.70	2.80	3.50	3.30	4.20	3.75	2.50	4.30	4.20	4.30	4.30	4.40
8	2.60	3.40	3.40	3.30	4.30	3.40	2.40	4.30	4.20	4.30	4.40	4.40
9	2.50	3.00	3.40	3.20	4.40	3.50	2.40	4.30	4.20	4.30	4.40	4.40
10	2.50	2.90	3.40	3.60	4.50	3.15	2.40	4.30	4.20	4.30	4.30	4.40
11	2.40	2.80	3.30	3.90	4.70	3.30	2.40	4.30	4.20	4.30	4.30	4.40
12	2.60	2.70	3.10	3.80	4.90	3.40	2.40	4.20	4.20	4.30	4.30	4.50
13	2.60	2.70	3.10	4.10	4.80	3.30	2.40	4.30	4.20	4.30	4.30	4.50
14	2.40	2.70	3.10	4.50	4.90	3.20	2.40	4.20	4.20	4.30	4.20	4.40
15	2.30	2.60	3.00	4.70	4.10	3.20	2.30	4.20	4.20	4.30	4.20	4.40
16	2.40	2.60	2.90	5.20	4.10	3.20	2.20	4.10	4.20	4.30	4.20	4.40
17	2.20	2.50	3.00	5.50	4.90	3.50	2.20	4.20	4.20	4.30	4.20	4.40
18	2.20	2.60	2.90	5.90	4.80	3.70	2.20	4.20	4.20	4.30	4.30	4.50
19	2.30	2.70	3.00	6.00	4.80	3.50	2.20	4.20	4.20	4.30	4.30	4.50
20	2.40	2.60	2.90	5.70	4.80	3.20	2.20	4.20	4.20	4.30	4.30	4.60
21	2.20	2.60	2.90	5.30	4.70	3.00	2.20	4.20	4.20	4.30	4.30	4.80
22	2.10	2.50	2.90	5.30	4.50	3.50	2.20	4.20	4.20	4.30	4.30	4.90
23	2.20	2.60	2.80	4.80	4.30	3.30	2.20	4.20	4.20	4.30	4.20	4.70
24	2.20	2.80	2.80	5.90	4.20	3.10	2.20	4.20	4.30	4.40	4.20	4.70
25	2.30	3.50	2.90	6.50	4.10	3.10	2.20	4.20	4.30	4.40	4.30	4.60
26	2.40	3.20	3.00	6.40	4.00	3.10	2.10	4.30	4.30	4.30	4.30	4.60
27	2.50	3.40	3.00	6.60	3.10	3.10	2.10	4.30	4.40	4.30	4.30	4.50
28	2.30	4.40	2.90	6.10	3.10	3.00	2.10	4.30	4.40	4.30	4.30	4.50
29	2.30	.....	2.80	5.90	3.90	3.00	2.10	4.30	4.30	4.30	4.30	4.50
30	2.40	.....	2.70	5.60	3.80	3.00	a 4.30	4.30	4.30	4.30	4.30	4.40
31	2.50	.....	3.10	.....	3.70	.....	4.30	4.30	.....	4.30	.....	4.30

a New rod placed July 30, 1898.

ıge height, in feet, of Tuolumne River at Lagrange, California, for 1898.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
..	4.80	4.50	5.80	5.50	6.85	5.90	5.00	3.90	3.90	3.65	3.55	4.75
..	4.80	4.50	5.80	5.50	6.70	5.90	4.80	3.90	3.90	3.80	3.50	4.60
..	4.80	4.50	5.60	5.50	6.60	5.80	4.80	3.90	3.80	3.90	3.55	4.25
..	4.80	4.50	5.50	5.40	6.60	5.80	4.80	4.00	3.60	3.80	3.60	4.10
..	4.80	4.60	5.50	5.45	6.40	5.90	4.70	3.90	3.10	3.70	3.55	4.00
..	4.70	4.80	5.50	5.55	6.40	6.20	4.60	3.90	3.10	3.70	3.55	4.00
..	5.00	4.70	5.50	5.85	6.40	6.40	4.50	3.90	3.10	3.70	3.40	3.90
..	4.80	5.70	5.50	5.75	6.60	6.25	4.50	3.90	3.10	3.70	3.25	3.90
..	4.80	5.20	5.50	5.45	6.90	6.10	4.50	3.90	3.00	3.70	3.20	3.80
..	4.80	5.00	5.80	5.80	7.30	6.00	4.50	3.85	3.00	3.70	3.20	3.75
..	4.70	5.00	5.50	6.10	7.50	6.20	4.50	3.90	3.00	3.70	3.20	3.70
..	4.70	5.00	5.30	6.15	7.40	6.20	4.50	3.90	3.00	3.70	3.20	3.65
..	4.70	5.00	5.30	6.50	7.40	6.20	4.40	3.95	3.00	3.70	3.20	3.75
..	4.70	5.00	5.30	6.70	7.40	6.20	4.50	3.90	3.00	3.60	3.30	3.70
..	4.70	5.10	5.20	6.85	7.40	6.20	4.50	3.90	3.00	3.60	3.30	3.65
..	4.70	5.00	5.10	6.85	7.70	6.30	4.40	3.90	3.00	3.60	3.30	3.40
..	4.70	5.20	5.30	7.05	7.30	6.20	4.40	3.90	3.00	3.60	3.35	3.70
..	4.70	5.20	5.20	7.00	7.20	6.10	4.40	3.90	3.00	3.55	3.35	3.75
..	4.70	5.00	5.00	7.05	7.30	6.00	4.30	3.90	3.00	3.50	3.35	3.75
..	4.60	5.00	5.00	7.10	7.20	5.90	4.20	3.85	3.00	3.50	3.35	3.80
..	4.60	5.00	5.00	6.80	7.20	5.80	4.20	3.90	3.10	3.50	3.40	4.55
..	4.60	5.00	5.00	6.65	7.40	5.60	4.10	3.90	3.10	3.50	3.45	5.80
..	4.60	5.00	5.10	6.40	6.20	5.50	4.20	3.90	3.10	3.50	3.50	5.60
..	4.60	5.00	5.10	8.00	6.20	5.40	4.10	3.80	3.10	3.50	3.60	4.50
..	4.50	6.00	5.20	8.00	6.20	5.30	4.10	3.80	3.30	3.45	3.80	4.40
..	4.50	5.50	5.30	8.00	6.80	5.30	4.00	3.80	3.30	3.45	3.85	4.20
..	4.50	5.50	5.40	7.85	6.70	5.30	4.10	3.80	3.40	3.45	3.75	4.20
..	4.50	6.00	5.30	7.70	6.50	5.30	4.00	3.80	3.50	3.40	3.70	4.20
..	4.50	.....	5.30	7.60	6.50	5.10	4.00	3.80	3.60	3.40	3.70	4.10
..	4.50	.....	5.30	6.95	6.10	5.00	4.00	3.80	3.60	3.45	3.70	4.10
..	4.50	.....	5.40	.....	5.90	.....	3.90	3.90	.....	3.50	.....	4.10

ge height, in feet, of San Joaquin River at Herndon, California, for 1898.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
...	3.17	3.08	3.25	3.42	4.96	4.29	4.00	3.00	2.58	3.17	2.58	2.50
...	3.08	3.08	3.33	3.46	4.96	4.79	3.92	3.00	2.58	3.17	2.58	2.83
...	3.08	3.08	3.21	3.50	5.08	4.54	3.58	3.00	2.58	3.08	2.58	2.83
...	3.08	3.08	3.21	3.46	4.71	4.46	3.50	3.00	2.50	3.04	2.58	2.67
...	3.00	2.92	3.17	3.42	4.71	4.42	3.50	3.00	2.50	2.92	2.58	2.58
...	3.00	3.00	3.37	3.46	4.50	4.54	3.50	3.00	2.50	2.92	2.58	2.58
...	3.00	3.25	3.37	3.62	4.46	4.87	3.50	3.00	2.50	2.92	2.58	2.58
...	3.08	3.75	3.42	3.62	4.62	4.96	3.67	2.92	2.50	2.92	2.58	2.58
...	3.08	3.54	3.42	3.58	4.71	4.79	3.58	2.92	2.50	2.92	2.58	2.58
...	3.08	3.33	3.50	3.83	4.83	4.62	3.62	2.83	2.50	2.92	2.50	2.50
...	3.08	3.29	3.62	3.83	5.46	4.42	3.54	2.83	2.42	2.92	2.50	2.50
...	3.00	3.17	3.33	4.21	5.87	4.58	3.50	2.83	2.42	2.83	2.50	2.42
...	2.92	3.17	3.33	4.29	5.71	4.87	3.50	2.83	2.42	2.83	2.50	2.42
...	3.00	3.17	3.25	4.67	5.46	4.87	3.42	2.83	2.42	2.92	2.50	2.42
...	3.00	3.17	3.33	4.96	5.33	4.79	3.42	2.83	2.42	2.83	2.50	2.42
...	3.08	3.17	3.33	5.04	5.25	4.70	3.42	2.83	2.33	2.83	2.50	2.42
...	3.00	3.25	3.33	5.04	4.92	4.96	3.42	2.83	2.33	2.92	2.50	2.42
...	3.00	3.17	3.29	5.17	4.92	5.21	3.30	2.83	2.33	2.92	2.50	2.42
...	3.00	3.17	3.25	5.37	4.92	5.08	3.16	2.83	2.33	2.83	2.50	2.50
...	3.00	3.25	3.25	5.54	4.83	4.96	3.17	2.75	2.33	2.83	2.50	2.50
...	3.00	3.25	3.17	5.58	4.66	4.96	3.08	2.75	2.33	2.83	2.50	2.50
...	3.08	3.17	3.17	4.96	4.50	4.70	3.08	2.75	2.33	2.75	2.50	3.54
...	3.08	3.17	3.17	5.00	4.50	4.58	3.08	2.75	2.33	2.75	2.50	3.17
...	3.08	3.25	3.17	5.25	4.50	4.33	3.00	2.58	2.33	2.75	2.50	2.96
...	3.00	3.33	3.17	5.83	4.50	4.25	3.00	2.58	2.33	2.75	2.50	2.83
...	3.00	3.37	3.25	6.17	4.75	4.25	3.00	2.58	2.33	2.75	2.50	2.75
...	3.00	3.50	3.25	6.13	5.33	4.29	3.00	2.58	2.46	2.67	2.50	2.67
...	3.00	3.25	3.25	6.04	5.25	4.46	3.00	2.58	4.12	2.67	2.50	2.67
...	3.08	.....	3.29	5.62	4.71	4.25	3.00	2.58	3.46	2.67	2.50	2.67
...	3.08	.....	3.33	5.25	4.62	4.00	2.92	2.58	3.37	2.58	2.50	2.67
...	3.08	.....	3.33	.....	4.37	.....	3.00	2.58	.....	2.58	.....	2.67

Daily gage height, in feet, of Kings River at Red Mountain, California, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.60	4.40	5.00	5.40	7.70	7.60	5.80	4.20	3.70	4.90	3.70	3.90
2	4.50	4.50	5.20	5.50	7.30	7.30	5.70	4.20	3.70	4.60	3.80	3.90
3	4.50	4.50	5.10	5.50	7.40	7.00	5.50	4.20	3.70	4.30	3.80	3.90
4	4.50	4.40	5.00	5.50	7.40	7.10	5.30	4.20	3.70	4.40	3.70	3.80
5	4.50	4.40	4.80	5.70	7.00	7.30	5.20	4.20	3.70	4.20	3.70	3.80
6	4.50	5.00	4.90	5.70	7.10	6.80	5.20	4.20	3.70	4.20	3.70	3.80
7	4.60	4.60	5.10	5.70	7.20	6.80	5.10	4.20	3.60	4.10	3.70	3.90
8	4.60	5.60	5.20	5.80	7.50	6.50	5.10	4.10	3.60	4.10	3.70	3.90
9	4.70	5.20	5.20	6.20	8.10	6.50	5.10	4.10	3.60	4.00	3.70	3.90
10	4.60	5.00	5.20	6.60	8.70	6.40	5.10	4.10	3.60	4.10	3.70	3.80
11	4.50	5.00	5.60	6.70	9.00	6.40	5.00	4.10	3.60	3.90	3.70	3.80
12	4.60	4.90	5.60	6.90	9.20	6.40	4.90	4.00	3.50	3.90	3.70	3.60
13	4.50	4.90	5.50	7.10	8.70	6.70	4.90	4.00	3.50	3.90	3.70	3.60
14	4.50	4.90	5.30	7.60	8.10	6.80	4.90	4.00	3.50	3.90	3.70	3.60
15	4.50	4.80	5.20	8.20	7.70	6.80	4.80	4.00	3.50	3.90	3.70	3.70
16	4.50	4.90	5.30	8.30	7.70	7.00	4.70	4.00	3.50	3.90	3.70	3.70
17	4.50	4.90	5.20	8.30	7.70	7.30	4.70	4.00	3.50	3.90	3.70	3.70
18	4.50	4.90	5.20	8.50	8.10	7.30	4.70	4.00	a3.50	3.90	3.70	3.70
19	4.50	4.90	5.00	8.70	7.60	6.80	4.70	4.00	3.50	3.90	3.70	3.70
20	4.40	4.70	4.50	8.70	7.30	6.70	4.50	4.00	3.50	3.90	3.80	3.70
21	4.40	4.70	5.00	7.70	7.20	6.70	4.50	3.90	3.50	3.90	3.90	6.00
22	4.30	4.70	5.00	7.80	7.30	6.50	4.50	3.90	3.50	3.90	3.90	5.00
23	4.40	4.70	5.00	8.40	7.40	6.30	4.40	3.80	3.50	3.80	3.80	4.00
24	4.30	4.60	5.10	8.70	7.30	6.30	4.40	3.80	3.50	3.80	3.80	3.90
25	4.30	5.40	5.20	9.10	7.60	6.10	4.40	3.80	3.50	3.80	3.80	4.00
26	4.30	5.10	5.20	9.40	8.50	6.40	4.30	3.80	3.50	3.80	3.80	4.00
27	4.40	5.00	5.10	9.50	8.10	6.20	4.30	3.70	3.60	3.70	3.70	4.00
28	4.30	5.00	5.20	9.70	7.50	5.90	4.30	3.80	3.90	3.70	3.80	4.00
29	4.30	.....	5.40	8.70	7.10	5.90	4.30	3.80	4.50	3.70	3.80	4.00
30	4.30	.....	5.50	7.70	7.10	5.80	4.30	3.80	5.00	3.70	3.80	3.90
31	4.30	.....	5.50	.....	7.10	.....	4.30	3.80	.....	3.70	.....	3.80

a No observations from September 18 to October 1. Values in table have been estimated.

Daily gage height, in feet, of Kings River at Kingsburg, California, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.70	3.50	2.75	3.83	6.00	5.50	3.12	3.66	3.46	4.21	3.42	4.04
2	4.25	3.50	3.00	3.75	5.58	5.50	3.62	3.50	3.46	4.00	3.38	4.23
3	3.83	3.50	3.04	3.83	5.08	5.08	3.75	3.25	3.46	3.87	3.50	4.17
4	3.87	3.46	3.00	3.83	4.71	4.75	3.46	3.17	3.50	3.75	3.58	4.17
5	3.83	3.42	3.21	3.79	4.37	4.75	3.54	3.17	3.46	3.66	3.67	4.04
6	3.70	3.50	3.17	4.00	3.58	5.17	3.54	3.08	3.46	3.83	3.58	4.04
7	3.70	4.37	3.13	4.12	3.79	4.96	3.79	3.04	3.42	3.83	3.50	4.00
8	3.75	5.83	3.08	4.00	4.42	4.92	4.04	3.08	3.42	3.75	3.48	4.00
9	4.00	4.75	3.17	4.14	4.58	4.50	3.96	3.04	3.42	3.83	3.58	3.98
10	3.75	3.42	3.21	4.04	5.42	4.21	3.92	3.00	3.37	3.75	3.58	4.00
11	3.75	3.00	4.17	4.21	6.00	3.75	3.96	3.00	3.42	3.75	3.58	3.96
12	3.50	2.87	4.00	4.50	6.33	3.46	4.00	3.00	3.33	3.75	3.58	4.00
13	3.08	2.58	3.87	4.54	6.33	4.17	4.00	3.00	3.33	3.75	3.48	3.92
14	3.46	2.75	3.54	4.87	6.08	5.04	4.04	3.00	3.33	3.66	3.42	3.96
15	3.17	2.66	3.50	5.17	5.83	5.08	4.08	3.00	3.33	3.70	3.42	4.00
16	3.50	2.92	3.46	5.47	5.83	5.17	4.00	2.96	3.33	3.83	3.50	3.96
17	3.50	3.12	3.38	5.40	5.50	4.83	4.00	2.92	3.33	3.75	3.50	4.00
18	3.75	3.08	3.29	5.66	5.42	4.58	4.08	2.92	3.42	3.79	3.42	3.98
19	3.54	3.00	3.29	6.14	5.75	4.50	4.17	3.46	3.33	3.77	3.42	4.00
20	3.50	3.00	3.33	6.70	5.33	4.25	4.04	3.38	3.33	3.75	3.62	4.08
21	3.50	3.13	3.37	6.66	4.83	4.75	3.38	3.46	3.33	3.73	3.62	4.08
22	3.50	3.08	3.33	5.91	5.58	4.79	3.17	3.46	3.33	3.60	3.79	6.17
23	3.50	3.00	3.50	5.62	5.92	4.50	3.21	3.50	3.33	3.58	3.75	4.87
24	3.58	2.96	3.50	6.08	6.00	4.12	3.62	3.42	3.33	3.58	3.92	4.25
25	3.66	2.96	3.50	6.75	6.00	3.79	3.75	3.42	3.66	3.66	4.00	3.83
26	3.33	3.00	3.75	7.12	5.75	3.42	3.92	3.42	3.70	3.50	3.96	3.67
27	3.50	2.50	3.75	7.08	6.50	3.42	3.83	3.42	3.91	3.50	3.92	4.00
28	3.50	2.75	3.54	7.00	6.00	3.50	3.83	3.42	6.00	3.50	4.00	3.96
29	3.50	.....	3.66	6.83	5.58	3.25	3.83	3.42	5.08	3.50	4.00	3.92
30	3.50	.....	3.75	6.00	5.92	3.00	3.75	3.42	4.62	3.42	4.00	4.00
31	3.50	.....	3.75	.....	5.67	.....	3.71	3.42	.....	3.42	.....	4.00

List of discharge measurements, 1898.

Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
			Feet.	*Sec.-feet.*
acramento River.	Jellys Ferry, Cal..	Fred Lemstrom ...	5.70	5,578
..do	....do	....do	8.30	13,118
..do	....do	....do	15.32	37,818
..do	....do	....do	6.95	9,495
..do	....do	....do	6.10	7,155
..do	....do	....do	6.10	7,216
..do	....do	....do	6.20	7,606
..do	....do	....do	5.50	5,473
..do	....do	....do	7.92	12,477
..do	....do	J. B. Lippincott ...	7.10	*a* 9,048
..do	....do	Fred Lemstrom ...	5.90	6,162
..do	....do	....do	5.45	5,093
..do	....do	....do	5.20	4,625
..do	....do	....do	5.10	4,520
..do	....do	....do	5.00	4,324
..do	....do	....do	5.00	4,089
..do	....do	....do	5.00	4,160
..do	....do	....do	5.10	4,322
..do	....do	....do	5.10	4,380
..do	....do	....do	5.15	4,271
..do	....do	....do	5.20	4,662
..do	....do	....do	5.20	4,367
tanislaus River...	Oakdale, Cal	J. B. Lippincott ...	5.30	2,203
..do	....do	....do	3.77	912
..do	....do	....do	*b* 4.30	73
..do	....do	....do	4.20	50
..do	....do	....do	4.97	362
uolumne River...	Lagrange, Cal.....	....do	7.18	5,762
..do	....do	....do	5.90	1,887
..do	....do	....do	*c* 3.95	103
..do	....do	....do	3.00	0.00
..do	....do	....do	3.70	83
an Joaquin River.	Herndon, Cal	....do	5.42	4,162
..do	....do	....do	4.58	2,235
..do	....do	....do	3.00	611
..do	....do	....do	2.52	328
..do	....do	....do	2.50	287
ings River.....	Red Mountain, Cal.	....do	8.55	4,943
..do	....do	....do	7.14	2,672
..do	....do	....do	4.32	503
..do	....do	....do	3.77	244
..do	....do	....do	7.00	2,444
..do	Kingsburg, Cal	....do	6.58	*d* 1,658
..do	....do	....do	6.58	*d* 1,658
..do	....do	....do	6.19	*e* 1,026
..do	....do	....do	3.92	*d* 305
..do	....do	....do	3.92	*e* 305
..do	....do	....do	3.42	*d* 94

g meter No. 67; using meter No. 12 the discharge was 9,290 second-feet.
rod; reading on old rod 2.10.
ptember 9 at gage height 3.00 the discharge stopped.
R. R. Bridge.
s Bridge.

List of miscellaneous discharge measurements, 1898.

Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
			Feet.	*Sec.-feet.*
and S. J. V. Canal.	Knights Ferry	J. B. Lippincott ...	−2.39	24
..do	....do	....do	−1.62	44
..do	....do	....do	−1.12	61
..do	....do	....do	−3.89	0
..do		....do	.....	33
orth Fork of Kern River. *a*	"A" Channel	Frank H. Olmsted.	.....	17
..do	"B" Channel.....	....do	.....	199
..do	"C" Channel.....	....do	.....	107
..do	"D" Channel.....	....do	.....	8
..do	Total	....do	.....	331
outh Fork *b*.....	.....	....do	.....	13

a Above junction with South Fork.
b *At a point 700 feet* above junction with North Fork.

Rating tables.

Jellys Ferry.		Oakdale. *a*		Oakdale. *b*		Lagrange.		Herndon.		Red Mountain.	
Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
5.0	4,250	2.1	74	4.2	50	3.0	.....	2.4	240	3.5	145
5.1	4,475	2.2	114	4.3	74	3.1	8	2.5	290	3.6	180
5.2	4,700	2.3	156	4.4	100	3.2	16	2.6	350	3.7	215
5.3	4,925	2.4	198	4.5	130	3.3	24	2.7	410	3.8	250
5.4	5,150	2.5	240	4.6	165	3.4	32	2.8	470	3.9	285
5.6	5,605	2.6	280	4.7	205	3.6	52	2.9	530	4.0	330
5.8	6,065	2.7	336	4.8	255	3.8	76	3.0	610	4.2	400
6.0	6,525	2.8	384	4.9	315	4.0	100	3.1	712	4.4	480
6.2	7,015	2.9	432	5.0	385	4.2	180	3.2	814	4.6	572
6.4	7,505	3.0	480	.....	.....	4.4	260	3.3	916	4.8	676
6.6	8,000	3.2	592	.....	.....	4.6	390	3.4	1,018	5.0	780
6.8	8,500	3.4	704	.....	.....	4.8	570	3.5	1,120	5.2	908
7.0	9,000	3.6	820	.....	.....	5.0	750	3.6	1,242	5.4	1,036
7.2	9,600	3.8	940	.....	.....	5.2	1,010	3.7	1,364	5.6	1,170
7.4	10,200	4.0	1,060	.....	.....	5.4	1,270	3.8	1,486	5.8	1,310
7.6	10,800	4.2	1,216	.....	.....	5.6	1,620	3.9	1,608	6.0	1,450
7.8	11,400	4.4	1,372	.....	.....	5.8	2,060	4.0	1,730	6.2	1,642
8.0	12,000	4.6	1,540	.....	.....	6.0	2,500	4.2	2,034	6.4	1,834
8.2	12,600	4.8	1,720	.....	.....	6.2	3,020	4.4	2,338	6.6	2,034
8.4	13,200	5.0	1,900	.....	.....	6.4	3,540	4.6	2,660	6.8	2,242
8.6	13,800	5.2	2,108	.....	.....	6.6	4,060	4.8	3,000	7.0	2,450
8.8	14,400	5.4	2,316	.....	.....	6.8	4,580	5.0	3,340	7.2	2,718
9.0	15,000	5.6	2,540	.....	.....	7.0	5,100	5.2	3,744	7.4	2,986
9.2	15,600	5.8	2,780	.....	.....	7.2	5,620	5.4	4,148	7.6	3,280
9.4	16,200	6.0	3,020	.....	.....	7.4	6,140	5.6	4,576	7.8	3,600
9.6	16,800	6.2	3,320	.....	.....	7.6	6,680	5.8	5,028	8.0	3,920
9.8	17,400	6.4	3,620	.....	.....	7.8	7,240	6.0	5,480	8.5	4,870
10.0	18,000	.....	.....	.....	.....	8.0	7,800	6.2	5,968	9.0	6,000
10.5	19,500	.....	.....	.....	.....	8.2	8,400	6.4	6,456	9.5	7,300
11.0	21,000	.....	.....	.....	.....	8.4	9,000	6.6	6,944	.....	.....

a Applicable from January 1 to July 29, 1898. Gage heights refer to old gage.
b Applicable from July 30 to December 31, 1898. Gage heights refer to new gage.

SOUTHERN CALIFORNIA DRAINAGE.

The river stations in southern California are under the charge of Mr. J. B. Lippincott, of Los Angeles. The streams are relatively small, and computations of discharge are based largely upon weir measurements and similar methods.

DESCRIPTION OF RIVER STATIONS.

Palmdale station on Littlerock Creek.—Described on page 193 of Paper No. 16; results for 1897 given on page 526 of the Nineteenth Annual Report, Part IV. The stream was dry from June 4 to the end of 1898. All of the water of the stream throughout the year has been diverted into the flume of the South Antelope Valley Irrigation Company at its headworks in the canyon. This water company has kept these records and furnished them without expense through the courtesy of Burt Cole, chief engineer. On January 4, 1898, a float measurement was made during low stage of water in Pallet Creek. The gage height was 0.52 and the discharge 0.78 second-feet. On the same date a measurement was made of Bigrock Creek opposite the dam site near Pallet Creek in Bigrock Creek. At that time the gage height was 5.70 and the discharge 5.27 second-feet. On this date also a current-meter measurement was made in the development tunnel on

k Creek, showing that the total developed water equals 1.33 l-feet. On February 20 a current-meter measurement was by Burt Cole at the Littlerock Creek gaging station in the The height of water was 2.76 feet and the discharge 5.11 l-feet. On March 2 a measurement above the head gate of the ock Creek irrigation district showed there was flowing 2.02 l-feet. A float measurement of this water after flowing in the or about a mile gave a discharge of 1.60 second-feet.

sa station on San Gabriel River.—Described on page 194 of No. 16; results given on page 528 of the Nineteenth Annual t, Part IV. No water was flowing from February 24 to March 9, om March 11 to May 4, from May 6 to May 15, and from May he end of the year.

y observations have been made on the river by H. F. Parkinson, isa, the superintendent in charge of the division of the water stream for all the companies diverting water at the mouth of nyon. The entire output of the stream, practically, has been ed into the canals of these companies and measured daily weirs during 1898. A large number of separate diversions and a number of weirs have been used in this computation. these records have been kept in detail by Mr. Parkinson, it is ered unnecessary and confusing to give rating tables for all irs and the volumes diverted over each; herewith are given a of gage heights and a rating table for the river at the gaging n, and a table showing the combined flow of the ditches for the September 1 to December 31.

isual difficulties have been encountered in obtaining rating for the river rod. In 1897 the Vinelead irrigation district ucted a small diversion dam a short distance below the gage, compelled its removal to a point higher up the stream. The as moved, and all readings for the first portion of 1898 were on this rod. During the summer of 1898 this rod was destroyed known parties. In the fall of 1898 a final rod was placed at me place as its immediate predecessor, and readings were taken n. Because of the extremely low rainfall there have been ew opportunities to rate these rods. A curve has been platted, t from measurements and in part from comparative results of rements on older rods. It is believed that this table is suffi- accurate to give fairly good results for the small volumes of that have passed these rods during the past year. A rating s given for the Slaughter House tunnel on the Azusa Canal. e rod is located at the lower end of this tunnel, on the right- side of the conduit. During the ordinary low summer stages the entire volume of water supply passes this point, and the iversions may be obtained from observations here. Prior to the etion of the weirs of the power company, described below, this e point of measurement for the diverted waters of the stream.

The cable that was used in the past for the measurement of floods having become old and rusty, not being the property of the Geological Survey, and not being favorably situated for the measurements of floods, was abandoned. A new cable has been stretched across the river by the Geological Survey and a new car made at a point near the present gage rod in the main stream. The San Gabriel Electric Company during the past year has constructed a conduit of 4,000 inches capacity, diverting the water of the river at a point about six miles above the mouth of the canyon from the left bank of the stream and discharging it through a power house at the mouth of the canyon at a point below the gage rod in the river. Weirs have been constructed at the power house equal to the 4,000 inches, and if there is any excess water that the canal companies do not desire which is run through the power house by the electric company, it is wasted in the river below the gage; consequently a wholly new condition of affairs will exist during the year 1899 from that which existed during previous years. Arrangements have been made with the electric company by which they give access to their records, which are kept by automatic recording gages, both on the weirs at the power house and the weirs at the point of diversion. Mr. George Newman, chief engineer of this company, has shown the courtesy of offering this data without charge. This will result in a greatly improved record in the future. The discharge measurements shown on page 190 were made by J. B. Lippincott during 1898.

Warmsprings station on Santa Ana River.—Described on page 195 of Paper No. 16; results for 1897 given on page 567 of the Nineteenth Annual Report, Part IV. It is located 5 miles northeast of Mentone, California, three-fourths of a mile below the headworks of the Santa Ana Canal and opposite Warm Springs in the canyon. The gage is an inclined timber, the lower end of which has been set under the projecting edge of a large bowlder and fastened to upright posts at its upper end. On October 16, owing to some local legal conditions, an unusually large volume of water was turned into the Santa Ana Canal by the Bear Valley Company. This water was wasted from the canal at a point below the old gage rod. Every effort has been made to seek cooperation of the Bear Valley Company in perfecting the records of this stream, in order that they may be as accurate as it is possible to get them. This company has, however, declined to cooperate in this work, and refused to give the records of the amount diverted into their various canals. Individual measurements were made of these canals whenever a gaging was made of the stream itself. The only diversion above the gaging station is into the Santa Ana Canal, but it is probable that there was some fluctuation therein between the dates of measurements of its diversions. The above-mentioned conditions necessitated the establishment of a new gaging rod upon this stream at a point below where the waste from the canal

eturned into the river. This was done on November 9, 1898, and ince that date daily observations have been kept on the lower gage. This new gage is situated where the river flows at the foot of a ranite cliff, about 800 feet below the mouth of Warm Springs Canyon nd 100 feet above a road crossing the river. A vertical wooden gage od has been bolted to the rock bluff which forms the left bank of ie river. Since November 9, 1898, observations have been made on ie new gage rod bolted to the cliff.

Mill Creek.—An effort has been made to obtain the daily records of ow of water in Mill Creek, but local companies have considered it gainst their interests to furnish these for publication. Individual ieasurements have been made of the stream at the head of the zanja, ich time the Santa Ana was visited, and, owing to the absence of oods and the conditions of low water throughout southern Cali- ornia during the year 1898, these separate measurements may be iken as fairly representing the discharge of the stream.

TABLES OF DAILY GAGE HEIGHT.

Daily gage height, in feet, of Littlerock Creek at Palmdale, California, for 1898. (*a*)

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	Day.	Jan.	Feb.	Mar.	Apr.	May.	June.
1	0.35	0.40	0.38	0.42	0.31	0.20	17	0.40	0.40	0.39	0.39	0.56	.....
2	.35	.40	.38	.42	.27	.10	18	.40	.40	.38	.38	.53	.....
3	.35	.40	.38	.45	.27	.00	19	.40	.40	.39	.38	.48	.....
4	.35	.40	.38	.45	.25	.....	20	.40	.40	.40	.37	.47	.....
5	.35	.40	.38	.45	.26	.....	21	.40	.38	.40	.36	.41	.....
6	.35	.40	.38	.45	.35	.....	22	.40	.38	.40	.36	.42	.....
7	.35	.50	.38	.45	.33	.....	23	.40	.38	.38	.36	.38	.....
8	.40	.85	.38	.43	.32	.....	24	.40	.35	.38	.32	.37	.....
9	.40	.61	.38	.41	.32	.....	25	.40	.35	.38	.29	.34	.....
10	.40	.50	.40	.40	.28	.....	26	.40	.40	.40	.28	.31	.....
11	.40	.48	.42	.40	.26	.....	27	.40	.40	.40	.28	.29	.....
12	.40	.45	.40	.40	.24	.....	28	.40	.33	.40	.27	.27	.....
13	.40	.42	.38	.40	.22	.....	29	.40	.....	.41	.28	.25	.....
14	.40	.41	.39	.40	.22	.....	30	.40	.....	.42	.29	.22	.....
15	.50	.41	.39	.39	.24	.....	31	.40	.....	.41	.....	.20	.....
16	.40	.41	.39	.39	.72	.....							

a June 4 to December 31, dry.

Daily gage height, in feet, of San Gabriel River at Azusa, California, for 1898. (*a*)

[Below canal diversions.]

Day.	Jan.	Feb.	Mar.	May.	Day.	Jan.	Feb.	Mar.	May.
1	0.0	0.98	.....	.....	17	1.23	1.50	.....	1.03
2	.0	.98	.....	.....	18	1.22	1.05	.....	1.00
3	.0	.98	.....	.....	19	1.20	1.05	.....	1.02
4	.0	.98	.....	.....	20	1.19	1.05	.....	1.00
5	.0	.52	.....	1.08	21	1.18	1.04	.....	.....
6	.0	.52	.....	.0	22	1.18	1.03	.....	.....
7	.0	.52	.....	.0	23	1.17	1.00	.....	.....
8	.0	1.65	.....	.0	24	1.17	.....	.....	.....
9	1.40	1.50	.....	.0	25	1.17	.....	.....	.....
10	1.50	1.40	0.67	.0	26	1.17	.....	.....	.....
11	1.40	1.30	.....	.0	27	1.17	.....	.....	.....
12	1.36	1.15	.....	.0	28	1.17	.....	.....	.....
13	1.35	1.10	.....	.0	29	1.17	.....	.....	.....
14	1.34	1.05	.....	.0	30	1.17	.....	.....	.....
15	1.30	1.00	.....	1.90	31	.98	.....	.....	.....
16	1.28	1.50	.....	1.35					

a River dry from February 24 to March 9, from March 11 to May 4, May 6 to May 15, and from May 21 to end of year.

Daily discharge in cubic feet, per second, of San Gabriel Canals, measured over weirs near Azusa, California, 1898. (River dry.)

[Watershed 222 sq. mi.]

Date.	Sept.	Oct.	Nov.	Dec.	Date.	Sept.	Oct.	Nov.	Dec.
	Sec.-ft.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*		*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*
1	8.2	9.0	9.0	11.7	18	6.5	8.0	9.0	15.0
2	10.0	9.8	8.5	11.8	19	6.5	8.4	10.1	14.4
3	8.2	10.0	8.5	11.8	20	6.1	8.6	10.5	14.5
4	8.2	10.5	8.0	11.9	21	7.5	7.9	10.5	14.5
5	8.2	9.0	8.5	11.9	22	7.5	8.2	10.5	14.5
6	8.2	9.0	9.0	11.9	23	7.5	9.0	11.2	14.5
7	7.9	8.5	9.0	12.0	24	7.5	10.0	11.2	14.5
8	7.9	8.5	9.0	12.0	25	8.5	9.0	10.5	14.8
9	8.0	8.5	8.5	12.0	26	8.5	9.1	10.5	14.0
10	8.0	9.0	8.7	12.2	27	7.5	9.1	10.5	14.0
11	7.5	8.7	9.0	12.5	28	10.2	8.9	11.0	14.0
12	7.5	8.0	9.8	12.6	29	8.0	8.9	11.5	14.3
13	7.5	8.0	9.8	12.6	30	10.2	8.4	11.5	14.0
14	7.5	7.5	9.2	12.6	31	.....	8.4	.....	14.5
15	7.0	7.5	9.8	18.2					
16	7.0	7.5	9.8	15.2	Mean	7.8	8.7	9.8	13.5
17	6.7	8.0	9.8	15.0					

Daily gage height, in feet, of Santa Ana River at Warmsprings, California, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.00	1.05	1.00	1.02	1.10	1.17	1.10	1.10	1.05	1.05	.....	2.1
2	1.00	1.05	1.00	1.02	1.10	1.15	1.12	1.10	1.05	1.00	.....	2.1
3	1.00	1.05	.97	1.00	.90	1.15	1.13	1.10	1.05	.90	.....	2.1
4	1.00	1.05	.95	1.00	.90	1.05	1.10	1.10	1.05	.90	.....	2.1
5	1.00	1.05	.95	1.00	.85	1.05	1.10	1.07	1.05	.90	.....	2.1
6	1.00	1.35	1.00	1.00	.85	1.15	1.10	1.05	.90	.85	.....	2.1
7	1.00	1.35	1.05	1.00	.85	1.15	1.07	1.00	.90	.80	.....	2.1
8	1.00	1.25	1.05	1.00	.85	1.10	1.07	1.10	.92	.80	.....	2.1
9	1.00	1.20	1.05	1.00	.95	1.10	1.07	1.20	1.10	1.00	.....	2.2
10	1.45	1.15	1.05	1.02	.95	1.15	1.15	1.25	1.15	1.00	2.1	2.1
11	1.15	1.15	1.03	1.00	1.40	1.15	1.15	1.25	1.15	.97	2.1	2.1
12	1.15	1.10	1.07	.91	1.40	1.10	1.22	1.22	1.15	.95	2.1	2.1
13	1.15	1.07	1.10	.91	1.30	1.10	1.20	1.20	1.12	.95	2.1	2.1
14	1.15	1.05	1.00	1.00	1.30	1.10	1.15	1.17	1.10	.95	2.1	2.1
15	1.10	1.05	1.03	1.02	1.60	1.05	1.15	1.15	1.05	.95	2.1	2.1
16	1.10	1.05	1.05	1.02	1.40	1.05	1.15	1.12	1.00	(*a*)	2.1	2.1
17	1.10	1.05	1.00	1.02	1.30	1.05	1.07	1.15	.95	.....	2.1	2.1
18	1.10	1.10	.90	.97	1.30	1.05	1.00	1.15	1.03	.....	2.1	2.1
19	1.10	1.05	.90	.97	1.25	1.05	1.00	1.15	1.07	.....	2.1	2.1
20	1.10	1.05	.87	.95	1.25	1.05	1.10	1.15	1.00	.....	2.3	2.1
21	1.10	1.05	1.00	.95	1.25	1.22	1.12	1.05	1.05	.....	2.2	2.1
22	1.15	1.00	.82	.92	1.25	1.25	1.12	1.05	1.05	.....	2.1	2.1
23	1.25	1.00	.82	.92	1.20	1.25	1.12	1.05	1.05	.....	2.1	2.1
24	1.10	1.00	.85	.92	1.20	1.25	1.12	1.00	1.05	.....	2.1	2.1
25	1.00	1.00	.90	.92	1.20	1.25	1.10	1.10	1.05	.....	2.1	2.1
26	1.00	1.00	1.05	.92	1.20	1.25	1.05	1.00	.92	.....	2.1	2.1
27	1.00	1.00	.95	.90	1.25	1.12	1.10	1.10	.95	.....	2.1	2.1
28	1.05	1.00	1.00	.90	1.25	1.12	1.10	1.00	1.00	.....	2.1	2.1
29	1.05	.....	1.00	.90	1.25	1.10	1.10	1.05	1.05	.....	3.1	2.1
30	1.05	.....	1.00	.90	1.25	1.10	1.10	1.05	1.05	.....	2.1	2.1
31	1.05	.....	1.02	.....	1.20	.....	1.10	1.05	.....	.....	.....	2.1

a Weir measurements were made from October 16 to November 9.

List of discharge measurements.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
1898.				*Feet.*	*Sec.-feet.*
Jan. 4	Pallet Creek	Palmdale, Cal	J. B. Lippincott	.....	*a* 0.78
Do.	Bigrock Creek	do	do	.....	*b* 5.27
Do.	do	do	do	.....	*c* 1.33
Feb. 20	Littlerock Creek	do	Burt Cole	0.39	*d* 5.11
Mar. 2	do	do	do	.....	*e* 2.02
Do.	do	do	do	.....	*f* 1.60
Jan. 12	San Gabriel River	Azusa, Cal	J. B. Lippincott	1.36	23.29
Mar. 8	do	do	do	.....	*g* 49.16

a Low stage of water.
b Opposite dam site near where Pallet Creek enters Bigrock Creek.
c In development tunnel, Bigrock Creek.
d Gaging in flume.
e Water above head gate, Littlerock Creek irrigation district, turned into head gate.
f Measurement of above water after traveling in ditch 1 mile.
g Total in canals.

List of discharge measurements—Continued.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
1898.				*Feet.*	*Sec.-feet.*
Apr. 2	San Gabriel River.	Azusa, Cal.	J. B. Lippincott	.....	a41.00
May 17	do	do	do	1.03	15.40
July 21	do	Power Canal head.	do	4.06	13.21
Aug. 8	do	do	do	3.02	8.42
1897.					
Apr. 30	Azusa Canal	Tunnel	J. A. Vogleson	2.70	55.00
Aug. 7	do	do	A. Q. Campbell	1.80	24.00
Sept. 1	do	do	do	1.58	18.00
Sept. 29	do	do	do	1.35	14.00
Nov. 13	do	do	do	1.54	20.00
Nov. 27	do	do	J. B. Lippincott	1.64	21.00
1898.					
Mar. 8	do	do	H. F. Crowe	2.28	37.00
Apr. 2	do	do	J. B. Lippincott	1.95	30.00
May 10	do	do	do	1.70	23.00
May 17	do	do	do	2.10	32.00
July 1	do	do	F. H. Olmsted	.....	11.78
1897.					
Nov. 13	Duarte Canal	Below division box	A. Q. Campbell	.52	5.35
Nov. 27	do	do	J. B. Lippincott	.85	11.80
1898.					
Jan. 12	do	do	do	.675	8.25
Do.	do	do	do	.40	3.45
Do.	do	do	do	.275	1.81
Do.	do	do	do	.92	12.52
Mar. 8	do	do	H. F. Crowe	.79	12.30
Apr. 2	do	do	J. B. Lippincott	.84	11.30
May 17	do	do	do	.92	13.00
Jan. 8	Santa Ana River	Warmsprings, Cal.	do	1.00	25.56
Do.	Santa Ana Canal	do	do	.....	8.72
Mar. 9	Santa Ana River	do	H. F. Crowe	1.05	43.78
Do.	Santa Ana Canal	do	do	.....	7.04
Apr. 11	Santa Ana River	do	J. B. Lippincott	.97	31.61
Do.	Santa Ana Canal	do	do	.....	7.67
Apr. 29	Santa Ana River	do	do	.90	29.67
Do.	Santa Ana Canal	do	do	.....	8.00
June 12	Santa Ana River	do	do	1.10	35.14
Do.	Santa Ana Canal	do	do	.....	3.92
July 23	Santa Ana River	do	do	1.10	42.22
Do.	Santa Ana Canal	do	do	.....	5.34
Sept. 8	Santa Ana River	do	do	1.05	35.01
Do.	Santa Ana Canal	do	do	.....	1.66
Oct. 18	Santa Ana River	do	F. H. Olmsted	.95	22.78
Do.	Santa Ana Canal	do	do	.....	7.92
Nov. 9	Santa Ana River	do	do	b2.10	21.78
Dec. 8	do	do	do	b2.13	24.74

Total in canals.
New gage rod established on November 9 below discharge of Santa Ana Canal waste gate.

Rating tables.

Palmdale.		Azusa.		Azusa Canal Tunnel.		Warmsprings. a		Warmsprings. b	
Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*
0.0	0.0	0.4	0.0	1.0	9.0	0.80	25	2.10	22
.1	.5	.5	.2	1.1	10.6	.85	26	2.15	25
.2	2.0	.6	.5	1.2	12.2	.90	28	2.20	28
.3	4.0	.7	1.2	1.3	13.9	.95	30	2.25	31
.4	6.0	.8	3.0	1.4	15.8	1.00	33	2.30	34
.5	9.0	.9	6.0	1.5	17.8	1.05	36	2.35	38
.6	12.0	1.0	9.0	1.6	19.8	1.10	40	2.40	42
.8	19.0	1.1	13.0	1.7	22.0	1.15	45	.....	.....
1.0	27.0	1.2	17.0	1.8	24.3	1.20	51	.....	.....
1.2	35.0	1.3	21.0	1.9	26.9	1.25	58	.....	.....
1.4	44.0	1.4	26.0	2.0	29.5	1.30	66	.....	.....
1.6	54.0	1.5	31.0	2.1	32.5	1.35	76	.....	.....
1.8	64.0	1.6	38.0	2.2	35.6	1.40	87	.....	.....
2.0	75.0	1.7	45.0	2.3	39.0	1.45	99	.....	.....
2.2	86.0	1.8	53.0	2.4	42.8	1.50	112	.....	.....
2.4	96.0	1.9	63.0	2.5	46.6	1.55	129	.....	.....
2.6	108.0	2.0	80.0	2.6	50.8	1.60	149	.....	.....
2.8	120.0	.....	.....	2.7	55.2	.....	.....	.....	.....

a Applicable from January 1 to November 8, 1898.
b Applicable from November 9 to December 31, 1898.

List of miscellaneous discharge measurements (California), 1898

Date.	Stream.	Locality.	Hydrographer.	Gage height.	cl
				Feet.	*Se*
Aug. 24	San Gabriel River	Developed in Azusa tunnels.	J. B. Lippincott		
Do.	do	Pumped by Azusa at canyon mouth.	do		
Apr. 12	Mill Creek	Division box	J. B. Lippincott		
Do.	Green Spot pipe line.		do		
Apr. 29	do	Mill Creek	do		
Do.	Mill Creek	Division box	do		b
Oct. 18	do	Crafton division box.	F. H. Olmsted		b
Nov. 9	do	Division box	do		
Mar. 9	Santa Ana River	Weir at head of Highlands Canal.	H. F. Crowe		b
Do.	do	Flume near pressure box, Redlands Canal.	do		
Apr. 29	Santa Ana Canal	Headworks	J. B. Lippincott		b
June 20	Santa Ana, south channel.	Narrows below Riverside.	F. H. Olmsted		
Do.	Santa Ana, north channel.	do	do		
	Total				
Aug. 28	Santa Ana River	400 feet below Riverside Bridge.	do		
Do.	do	Near head Roubidoux Ditch.	do		
Aug. 29	do	Below Riverside, at Narrows.	do		
Do.	do	do	do		
Do.	do	Rincon Narrows	do		
Aug. 30	do	Postierra Ditch	do		
Oct. 18	do	Redlands Canal	do	.34	
Do.	do	Head Highlands Ditch.	do		
Do.	Head Green Spot pipe line.	Santa Ana	do		
Nov. 9	Santa Ana River	Head Santa Ana Canal.	do		b
Do.	do	Redlands Canal in flume.	do		b
Do.	do	Head Green Spot pipe line.	do		
Do.	do	Head Highlands Ditch.	do		
Dec. 8	do	Head Green Spot pipe line.	do		
Do.	do	Head Santa Ana Canal.	do		
June 28	Los Angeles River	Bridge No. 2	J. B. Lippincott	.92	
Do.	do	Main Supply Ditch	do	2.35	
Apr. 29	Highland Canal, north fork.	Headworks	do		b
Do.	Redlands Canal	do	do		
June 10	Lytle Creek	do	do		b
Do.	Rialto Canal	Weir	do		
Do.	Grapeland Canal		do		
June 20	Narrows Ditch		F. H. Olmsted		
July 23	Green Spot pipe line.	Headworks	J. B. Lippincott		
Aug. 12	Castaic	Near mouth	F. H. Olmsted		
Do.	Pacoima	Submerged dam	do		
Do.	Little Tejunga River.	Mouth	do		
Aug. 30	Chino Creek	Mains Rancho	do		
Aug. 21	Tulare Lake	Tulare County	do		

a Dry. b Weir.

LOW-WATER MEASUREMENTS.

The summer of 1898 has been one of very great drought throughout ; State of California. Not only has the seasonal rainfall been very ght, but it is a culmination of a number of unusually dry years. ıring the past eight years the annual rainfall with but one exception ; been below the average. Because of this shortage of water crop ›cial efforts have been made during the months of August and Sep- aber of 1898 to take measurements of the low water in numerous eams throughout the State upon which ordinarily no observations ve been taken. These measurements can be accepted as repre- ıting the minimum flow of the streams upon which they were taken. ıe following is a list of the midsummer measurements:

asurements of low-water stage in California during June, July, August, September, and October, 1898, by the United States Geological Survey.

Date.	Stream.	Locality.	Area of section.	Mean velocity.	Discharge.
			Sq. feet.		*Sec.-feet.*
June 2	Sacramento River.	Jellys Ferry	2,547.00	3.552	9,048.00
Sept. 13	do	do	1,802.00	2.3	4,152.00
Oct. 7	Yuba River	Dry, except for water from reservoir.			
Oct. 7	American River	North and Middle Fork, at head of North Fork Ditch.			16.00
Sept. —	do	At Folsom			34.50
June 1	Stanislaus River	Oakdale	486.00	1.875	911.50
June 2	do	Flume No. 3, Stanislaus and San Joaquin Canal.	24.10	3.00	72.35
July 29	do	Oakdale	167.00	.435	72.80
Do.	do	Stanislaus and San Joaquin Canal at Knights Ferry.			42.00
Oct. 6	do	Oakdale	145.20	.342	49.60
Oct. 5	do	Stanislaus and San Joaquin Canal.			33.40
Oct. 6	do	do			32.70
July 30	Tuolumne River	Lagrange	445.00	.232	103.20
Do.	do	Mining Company Ditch			24.00
Oct. 7	do	Lagrange	72.00	1.15	82.70
Do.	do	Mining Ditch			24.00
Do.	do	Turlock flume			30.00
	Total flow				136.70
July 28	San Joaquin River.	Herndon	665.00	.92	611.00
Sept. 2	do	do	520.00	.631	328.00
July 26	Kings River	Clarks Bridge	1,088.00	.28	305.00
July 25	do	Kingsburg Railroad bridge	1,290.00	.236	305.00
July 27	do	Red Mountain	452.00	1.13	503.00
Aug. 30	do	Kingsburg Railroad bridge	191.70	.492	94.10
Aug. 31	do	Red Mountain	333.50	.731	243.80
Do.	do	Church Ditch, check near Trimmer Spring road.	104.40	1.58	164.30
Do.	do	The 76 Ditch at mouth of canyon.			(a)
Do.	do	Fowler Switch Canal at mouth of canyon.			(a)
Do.	do	Kingsburg Ditch at mouth of canyon.			(a)
Sept. 1	Kaweah River	One-half mile above power company's headworks.	28.4	1.24	35.30
Do.	do	Iron bridge	34.2	.523	17.90
Do.	do	Irrigation and power ditch			8.50
Do.	do	Pogues Ditch			4.50
Do.	do	South Fork Kaweah, at junction.			(a)
Do.	do	North Fork Kaweah, at junction.			.30
Do.	Tule River	Headworks Pioneer Ditch (estimated).			6.00

a Dry.

Measurements of low-water stage in California during June, July, August, September, and October, 1898, etc.—Continued.

Date.	Stream.	Locality.	Area of section.	Mean velocity.	Discharge.
			Sq. feet.		*Sec.-feet.*
June 20	Warm Creek	Meek and Daily Ditch headworks.	(a)		8.42
Do.	do	Stout Ditch, lot 4, block 60, San Bernardino Rancho.			2.30
Do.	do	McKensie Ditch	2.90	.87	2.54
Do.	do	Rabel Ditch, lot 2, block 60	(a)		5.67
Do.	do	Beam Ditch			.67
June 7	do	Haws & Talmage first ditch, one-half mile west of Harlem.	.9	1.00	.90
June 30	do	Upper canal, Riverside Water Company, at old Colton Mill.	(a)		69.46
Sept. 21	do	do	(a)		61.34
Do.	do	Daily flume			.63
Do.	do	McKensie Ditch			2.16
Do.	do	Hays & Talmage			(b)
Do.	do	Rabel Ditch, at headworks			3.07
Sept. 22	do	Shay Ditch			2.08
June 10	Lytle Creek	Rialto Canal, Anglo-American division, Canaigre Company.	5.292	2.027	10.73
	do	McIntyre Ditch			.28
	do	San Bernardino Domestic Reservoir.			1.95
June 29	do	Whitings Ditch			.30
June 27	do	800 feet below Mount Vernon Bridge.	(a)		.28
Aug. 27	do	Gatehouse, Canaigre Company.	(a)		10.01
Sept. 22	do	Whitings Ditch			.10
Do.	do	McIntyre Ditch			.04
Do.	do	Carter Ditch			.003
June 11	West Twin Creek	Tollhouse, Waterman Canyon	.92	2.31	2.12
Sept. 9	do	Estimated			.38
June 11	East Twin Creek	K. C. Syndicate, flume	2.33	.83	1.95
Do.	do	K. C. Syndicate, developed			.11
		Total			2.06
Sept. 7	do	K. C. Syndicate			.73
June 11	City Creek	Headworks in canyon	2.295	1.32	3.03
June 29	do	Longsden & Farrell Ditch	.878	.82	.723
Do.	do	Whitlock Ditch	.209	1.16	.244
Do.	do	Daley Ditch across City Creek	.396	1.56	.62
Sept. 9	do	Headworks in canyon	.36	.20	.07
Sept. 21	do	Longsden & Farrell Ditch			.63
June 12	Plunge Creek	Headworks	1.565	1.446	2.26
Sept. 9	do	Estimated			.20
June 12	Santa Ana River	Warm Springs	18.25	1.923	35.14
Do.	do	Head Santa Ana Canal			3.92
	do	Total at mouth of canyon			39.06
Do.	do	Head North Fork Canal	(a)		11.37
Do.	do	Green Spot pipe line			.63
Do.	do	Bolen Tunnel	.32		1.24
Do.	do	Head Redlands Canal			18.40
Do.	do	Morton Canyon			.12
July 23	do	River at Warm Spring	21.57	1.96	42.22
Do.	do	Santa Ana Canal	(a)		5.34
	do	Total at mouth of canyon			47.56
Do.	do	Green Spot pipe line	(a)		2.2
Do.	do	Redlands Canal			15.0
June 29	do	Head Gage Canal in Santa Ana River.	(a)		1.16
Do.	do	Timber Ditch			(b)
June 30	do	Rice & Thorn flume, artesian			11.09
Do.	do	Below Ward & Warren Ditch			7.84
Do.	do	Diverted into W. & W. Ditch			.72
June 17	do	"A" + 1, one-half mile below S. C. R. bridge, Riverside to Colton.	6.19	1.57	9.742

a Weir. *b* Dry.

Measurements of low-water stage in California during June, July, August, September, and October, 1898, etc.—Continued.

Date.	Stream.	Locality.	Area of section.	Mean velocity.	Discharge.
			Sq. feet.		*Sec.-feet.*
June 17	Santa Ana River	Riverside Water Co. Ditch, left bank, 2 miles below S. C. R. bridge, Riverside to Colton, 4 p. m.	2.773	3.35	9.27
Do.	do	Same station, 10 a. m.	2.905	3.88	11.27
June 18	do	Jurupa Ditch at Agua Mansa.	6.39	2.16	13.83
June 19	do	Spring Brook "D," below Roubidoux hill.	1.10	2.65	2.92
Do.	do	"E" Ditch, right bank, one-half mile below Riverside bridge.	4.72	1.21	5.68
Do.	do	Roubidoux Ditch, near division "F."	4.28	2.08	8.94
Do.	do	River in Narrows, 4 miles below Riverside.	31.91	1.49	47.63
Do.	do	"H" Ditch, 5 miles below bridge, right bank.	3.04	1.23	3.75
Do.	do	"J" Griffith's place, right bank.	8.35	1.20	9.99
June 20	do	Ditch near bridge, Carona to Fullers.	5.87	.82	4.80
Do.	do	"K" Bridge, Carona to Fullers.	35.92	1.53	55.15
June 21	do	"N," 2 miles below Rincon, left bank.	2.05	1.55	3.18
Do.	do	"M," river in narrows 2 miles below Rincon.	46.54	1.71	79.81
June 22	do	Division gate S. A. V. Irrigation Co. and Anaheim Union Co.	40.52	1.66	67.47
Do.	do	5 miles below division box A. U. W. Co.	19.01	1.82	34.74
Do.	do	S. A. V. Irrigation Co. ditch near bridge to Yorba.	19.47	1.49	28.99
June 30	do	Gage Canal, Palm avenue	(a)		27.42
July 1	do	Jurupa Ditch			5.60
Sept. 8	do	River at Warm Springs	21.83	1.602	35.01
Do.	do	Santa Ana Canal			1.66
	do	Total at mouth of canyon			36.67
Do.	do	Bolen Tunnel			1.24
Do.	do	Green Spot pipe line			(b)
Do.	do	Head Highlands Canal			13.29
Do.	do	Alessandro, water in S. A. Canal.			1.66
Do.	do	Redlands Canal			15.40
Aug. 30	do	Total flow river, division box U. A. and S. A. V. Co.	28.33	1.86	52.89
Do.	do	Cement ditch S. A. V. I. Co.	16.54	1.49	24.62
Aug. 27	do	Jurupa Ditch	5.39	1.85	10.18
Do.	do	Total flow river 1½ miles below Riverside Water Co., lowest canal division.	.53	.94	.50
Do.	do	Head lower canal, Riverside	3.71	1.98	7.35
Aug. 28	do	Roubidoux Ditch, "C"	6.79	1.25	10.18
Do.	do	Ditch to Chinese garden	5.56	.88	4.87
Do.	do	Spring Brook	3.83	.37	1.27
Do.	do	River in narrows below Riverside.	27.16	1.44	39.05
Do.	do	River in Rincon Narrows	40.45	1.65	66.82
Sept. 22	do	Gage Canal, total flow	(a)		26.24
Do.	do	Davis Ditch			.37
June 12	Mill Creek	McIntosh water at road crossing.	.14	2.00	.28
Do.	do	Crafton Canal, total flow of creek.	1.92	9.42	18.10
July 23	do	do	(a)		11.82
Sept. 8	do	Crafton Canal, total flow of creek.	1.23	10.62	13.07
Do.	do	McIntosh water at road crossing.	.14	2.00	.28
June 24	Los Angeles River	In creek below Macy street			c .50
Do.	do	Diversion below Zanja No. 7	4.96	.013	.64
Do.	do	Zanja No. 7	4.05	1.38	5.59
Aug. 10	do	New bridge	(a)		1.28

a Weir. *b* Dry. *c* Approximate.

Measurements of low-water stage in California during June, July, August, September, and October, 1898, etc.—Continued.

Date.	Stream.	Locality.	Area of section.	Mean velocity.	Discharge.
			Sq. feet.		*Sec.-feet.*
Aug. 10	Los Angeles River.	San Fernando road crossing	(a)		4.84
Do.	do	North Cahuenga road	(a)		9.74
Do.	do	Old bridge No. 4	(a)		14.45
Do.	do	Tajunga Creek at junction	(a)		.87
Aug. 15	do	Bridge No. 2 at narrows	20.90	1.85	38.74
Do.	do	Main supply ditch	11.08	1.48	16.42
Do.	do	Total river at Crystal Springs			55.14
July 1	San Gabriel River.	Duarte water			3.59
Do.	do	Azusa water			11.78
June 21	do	Headworks in canyon	(a)		13.21
July 3	do	Temple Ditch	3.19	2.84	9.06
Do.	do	Baldwins Ranch house road, first channel.	6.30	1.30	8.79
Do.	do	Original channel of river	6.61	.93	6.18
Do.	do	Camper's station No. 11	4.06	.83	3.36
Do.	do	Puente Ditch			2.44
Do.	do	Old Mission Bridge	13.94	2.14	29.79
Do.	do	Total flow at Puente Narrows			61.63
Do.	do	Whittier Ditch	.88	2.86	2.52
Aug. 16	do	Headworks in canyon	(a)		5.16
Aug. 31	do	Flume Whittier Ditch	3.62	.50	1.80
Do.	do	Temple Ditch	2.67	2.57	6.88
Do.	do	Old channel	5.39	1.45	7.81
Do.	do	No. 10, No. 11	9.16	.67	6.17
Do.	do	Old Mission Bridge	13.61	2.05	27.91
Aug. 16	do	Total flow at Puente Narrows			52.60
Aug. 23	do	Headworks weir in canyon			8.42
Do.	do	Mouth East Fork	4.50	1.58	7.11
Do.	do	Mouth West Fork	3.47	.77	2.67
Do.	do	Azusa flume, lower tunnel developed water.	.356	.146	.52
July 1	do	Monrovia Canyon	1.36	.98	1.33
June 18	Santa Clara River.	Camulos Ranch	9.57	2.15	25.74
Aug. 11	do	2 miles east Camulos	9.23	1.88	17.36
Aug. 9	do	Flume one-half mile above San Francisquito Creek.	9.00	1.20	10.83
July 10 to July 17	Kern River	South Fork, 700 feet above junction.	8.03	1.61	12.94
	do	South Fork, near old engineer camp.	27.60	.65	17.85
	do	South Fork, sec. 6, T. 22 S., R. 36 E., M. D. M.	11.82	.85	10.05
	do	South Fork, Monache Meadows.	5.11	1.04	5.31
	do	North Fork, near junction			330.50
Aug. 29	do	First point of measurement, Bakersfield.	72.53	1.585	115.62
July 2	do	Monrovia Canyon	1.36	.98	1.33
Do.	San Antonio River.	In canyon	(a)		7.59
Do.	do	Ontario water, near division box.	.347	1.036	.36
Do.	do	Ontario water, below division box.	2.24	1.72	3.87
Do.	do	Pomona water at Pierces Camp.	1.97	1.70	3.36
Aug. 26	do	In canyon	(a)		10.01
Aug. 11	Sespe River	Division point	2.66	.92	2.46
Do.	Piru Creek	French House	1.46	.53	.92
Do.	San Francisquito Creek.		1.84	1.12	2.07
Do.	Little Tejunga River.				.05
Aug. 26	Cucamonga River.		.78	1.33	1.04
Sept. 16	Arroyo Seco	Total flow into Orange Grove avenue reservoir.	.318	1.88	.598
Do.	do	Flume pumped from Sheep Corral Springs.	2.32	.73	1.69
Do.	do	Marengo Improvement Co. reservoir.	.155	9.50	1.47
Do.	do	Reservoir No. 1 P. and L. V. L. and W. Co.	2.64	1.36	3.605
Do.	do	Tunnel junction Devils Gate, main supply.	2.70	1.02	2.75
Oct. 14	do	Reservoir No. 1			(b)
Sept. 7	Whitewater River.	Above Palm Valley Water Co. headworks.	4.14	2.26	9.35

a Weir. *b* Dry.

INDEX TO PAPERS NOS. 27 AND 28.

Page.

graphic work in 45, 48, 54–58
drographic work at 47, 49–50
., hydrographic work at. 59, 61, 65
drographic work at..... 31–32
drographic work at.. 28, 39, 44, 45
r, measurements of..... 45
easurements of 109, 114, 117
River, measurements of... 9, 14–16
measurements of.. 132, 139, 142, 145
, measurements of... 10, 19, 23, 24
hydrographic work at..... 131, 138–139, 142, 145
graphic work in 132–133, 140–143, 145
r, measurements of..... 107–108, 109, 110–112, 113–114, 116, 117
ydrographic work at.. 77, 83, 86, 89
, aid by..... 8, 155, 168, 169
easurements of 196
, hydrographic work at.... 59, 62, 65, 66
ydrographic work at 28–31, 40–41, 44, 46
ydrographic work at 118–119, 122–124, 129, 130
drographic work at. 187–188, 189–191
easurements of..... 191
rk of..... 29,
74, 75, 132, 142, 153, 155, 156, 168, 169
ork of..... 146, 153
laho, hydrographic work at. 146, 149, 153, 154
ork of..... 108, 109, 116
orado, measurements of.. 77, 81, 86
h, measurements of 146, 149, 150, 153, 154
measurement of..... 88
Creek, measurements of.... 77, 83, 86, 89
r, measurements of..... 156, 163, 168–169, 170
asurements of.... 131, 133, 142, 144
River, measurements of. 48, 56, 58
, measurements of 155–156, 163, 168, 170
drographic work at .. 131, 134, 144
asurements of..... 90, 94, 95, 96
ydrographic work at. 60, 64, 65, 66
ydrographic work at..... 155, 161, 168, 169
asurements of.... 155, 161, 168, 169
hydrographic work at 155, 156, 163, 168, 170
ydrographic work at. 77, 82, 86, 89
measurements of..... 77, 82, 86, 89
., hydrographic work at.... 68, 70, 74, 75
easurements of .. 118, 121, 129, 130
orgia, measurements of.... 31, 43, 44, 46
uth Carolina, measurements 27–28, 38–39, 44, 45
ork of..... 60, 65
ited..... 29
measurements of.... 155, 161, 169
ydrographic work at. 59, 63, 65, 66
hydrographic work at.. 10, 22, 24
ydrographic work at. 69, 73–74, 76
ydrographic work at. 133, 140, 142
., work of..... 23

Page.

Calhoun Falls, S. C., hydrographic work at. 28, 40, 44, 46
California, hydrographic work in.... 106, 177–196
Calowa River, measurements of..... 171, 175, 176
Camp Clarke, Nebr., hydrographic work at..... 76, 80, 86, 88
Campbell, A. Q., work of 191
Canton, Ga., hydrographic work at. 47–48, 51, 57, 58
Canyon, Colo., hydrographic work at..... 107, 110, 116, 117
Cape Fear River, measurements of... 26, 36, 44, 45
Carlton, Ga., hydrographic work at.. 31, 42, 44, 46
Carters, Ga., hydrographic work at. 45, 48, 52, 57, 58
Cary, Ga., hydrographic work at..... 31, 43, 44, 46
Catawba, N. C., hydrographic work at..... 27, 37, 44, 45
Catawba River, measurements of . 27, 37–38, 44, 45
Cedar River, measurements of 171, 172–173
Chattahoochee River, measurements of 45, 47, 50–51, 57, 58
Chattanooga, Tenn., hydrographic work at. 60, 64, 65, 66
Chinook, Mont., gaging station at..... 69
Clark, W. B., aid by..... 8
Clarksville, Va., hydrographic work at.. 25, 33, 44
Clear Creek, measurements of 69, 73–74, 76
Cogswell, F., work of..... 86
Cole, Burt, aid by 186, 190
Collinston, Utah, hydrographic work at 146, 150, 153, 154
Colorado, hydrographic work in..... 77–78, 81–84, 86, 89, 107–113, 116, 117, 120, 126, 129–132, 135–139, 142–145
Colorado River, measurements of 118–119, 122–124, 129, 130, 133, 141, 143
Colton, A. T., aid by..... 8, 132, 142
Columbus, Nebr., hydrographic work at. 78, 85, 87
Columbus, Ohio, hydrographic work at.... 60, 65
Conn, J. C., work of 44, 57, 65
Conversion tables 96–100
Coosa River, measurements of.... 48, 53–55, 57, 58
Coosawattee River, measurements of. 48, 52, 57, 58
Crowe, H. F., work of..... 191, 192
Dallas, Tex., hydrographic work at.. 118, 121, 129
Dan River, measurements of..... 25, 33, 44
Deep River, measurements of..... 26, 35, 44
Del Norte, Colo., hydrographic work at.... 120, 126, 129, 130
Delaware River, measurements of. 9, 16, 23, 24, 130
Denver, Colo., hydrographic work at. 77, 84, 86, 89
Deschutes River, measurements of... 159, 167, 169
District of Columbia, hydrographic work in 10, 22, 24
Dobson, Adna, aid by 8, 87, 95
Dolores, Colo., hydrographic work at..... 131, 138, 142, 144
Dolores River, measurements of.. 131, 138, 142, 144
Dougall, W. B., work of..... 146, 153
Duarte Canal, measurements of..... 191
Dublin, Ga., hydrographic work at... 31, 43, 44, 46
Dungeness River, measurements of.. 171, 174, 176
Durango, Colo., hydrographic work at..... 132, 139, 142, 145
El Paso, Tex., hydrographic work at..... 120, 128
Elk Creek, Nebraska, measurement of..... 88
Elk River, Colorado, measurement of 143
Elkhorn River, measurements of.... 78, 85, 87, 88
Elko, Nev., hydrographic work at..... 145–146, 147, 153, 154
Ellijay River, measurement of..... 45

Page.
Ellsworth, Kans., hydrographic work at .. 90, 93, 95, 96
Elrod, M. J., work of 168, 169
Elwha River, measurements of..... 171, 174, 176
Embudo, N. Mex., hydrographic work at .. 120, 127, 129, 130
Emery, Roe, aid by 8, 74-75
Emery, S. M., aid by 8
Etowah River, measurements of.. 47-48, 51, 57, 58
Fallcreek, Colo., hydrographic work at..... 131, 137, 142, 144
Farish, W. A., aid by 8, 143
Fayette, W. Va., hydrographic work at. 59, 62, 65
Fayetteville, N. C., hydrographic work at.. 26, 36, 44, 45
Fellows, A. L., aid by..... 8, 86, 107, 116, 142, 143
Field, J. E., work of 86
Flint River, measurements of..... 47, 49-50, 57, 58
Florence Canal, measurements of 142
Florida, hydrographic work in..... 45
Flynn, B. H., work of..... 60, 66, 67, 68
Forks, Wash., hydrographic work at. 171, 175, 176
Fort Crawford, Colo., hydrographic work at. 131, 136, 142, 144
Fort Niobrara, Nebr., gaging station at.... 69
Fortier, Samuel, aid by..... 8, 146, 153
Frederick, Md., hydrographic work at..... 10, 21, 24, 25
Fremont, Ohio, hydrographic work at..... 67, 68
French Broad River, measurements of..... 59, 62, 65, 66
Frenchman River, measurement of..... 88
Friendsville, Md., hydrographic work at..... 59, 61, 65
Gaffney, S. C., hydrographic work at. 27-28, 38, 44
Gallatin River, measurements of..... 68, 70, 74, 75
Geneva, Utah, hydrographic work at 146, 154
Georgia, hydrographic work in..... 28-32, 40-53, 57, 58, 60, 64-66
Gering, Nebr., hydrographic work at. 76, 80, 86, 88
Gibbon, Oreg., hydrographic work at..... 159, 167, 169, 170
Gila River, measurements of..... 133, 140, 142
Glasgow, Va., hydrographic work at.... 10, 22, 24
Golconda, Nev., hydrographic work at.... 146, 148, 153, 154
Granada, Colo., hydrographic work at... 109, 114
Grand Junction, Colo., hydrographic work at 131, 135, 136, 142, 144
Grand River, measurements of... 131, 135, 142, 144
Grandview, Idaho, hydrographic work at... 155, 161, 169
Granite, Colo., hydrographic work at 107, 110, 116, 117
Great Gunpowder River, measurements of. 24
Green River, measurements of. 131, 134, 142, 143, 144
Greenbrier River, measurements of..... 59, 61, 65
Greenriver, Wyo., hydrographic work at... 131, 134, 142, 144
Guadalupe River, measurements of .. 119, 124, 129
Gunnison River, measurements of. 131, 136, 142, 144
Hall, B. M., aid by..... 8, 29, 30, 31, 44, 45, 57, 65, 66
Hall, Max, work of..... 44, 45, 57, 65
Hall, O. P., work of..... 45, 57
Hall, Warren, work of..... 44, 45
Harrisburg, Pa., hydrographic work at.... 9, 17, 23, 24
Harroun, P. E., aid by..... 8, 129
Havre, Mont., hydrographic work at. 68, 72, 75, 76
Haw River, measurements of 25-26, 35, 44
Hawley, R. W., work of 116
Herndon, Cal., hydrographic work at... 179-180, 183, 185, 186, 193
High Bridge, Tex., hydrographic work at. 119-120, 126
Hiwassee River, measurements of..... 45, 60, 64, 65, 66
Holmes, J. A., aid by..... 8
Holston River, measurement of 66
Hood, O. P., work of..... 95
Hood River, measurements of..... 159, 168, 169
Hooper, Wash., hydrographic work at..... 155, 162, 168, 170
Humboldt River, measurements of..... 145-146, 147-149, 153, 154
Humphreys, D. C., aid by..... 8, 24, 44, 59, 65, 66
Hutchinson, Kans., hydrographic work at.. 109, 114, 116, 117
Idaho, hydrographic work in..... 149, 153-155, 159-162
Iola, Kans., hydrographic work at..... 115
James River, measurements of.....
Jefferson River, measurements of.... 68,
Jellys Ferry, Cal., hydrographic work at. 182, 185
Johnson, Charles, quoted.....
Johnston, C. T., aid by .....
Judson, N. C., hydrographic work at 59,
Junction City, Kans., hydrographic wo at..... 90,
Kansas, hydrographic work in 109, 110
Kansas River, measurements of... 90-91,
Kaweah River, measurements of.....
Kennebec River, measurements of.....
Kern River, measurements of..... 181
Kings River, measurements of..... 181, 184, 185
Kingsburg, Cal., hydrographic work at..
Kiona, Wash., hydrographic work at.... 163
Knights Ferry, Cal., hydrographic wo at .....
La Platte River, measurement of.....
Lagrange, Cal., hydrographic work at .. 183, 185
Lake Chelan, measurements of .. 157-158
Lake McDonald, measurements of.....
Lakeside, Wash., hydrographic work at..
Lambertville, N. J., hydrographic work
Laramie River, measurements of.. 76, 78-
Las Animas, Colo., hydrographic work n
Laurel, Md., hydrographic work at .. 10,
Laurel Hill Creek, measurement of .....
Lawrence, Kans., hydrographic work at
Lemstrom, Fred, work of .....
Lewis, Tex., hydrographic work at. 11
Liberty, Kans., hydrographic work at... 11
Ling, C. W., work of.....
Lippincott, J. B., aid by..... 106, 180, 185, 186, 188, 19
Little Snake River, measurement of....
Little Tejunga River, measurements of.
Little Tennessee River, measurements o
Little Wood River, measurements of... 16
Littlerock Creek, measurements of 18
Livingston, Mont., hydrographic work a
Logan, Mont., hydrographic work at. 68,
Logan, Utah, hydrographic work at.... 15
Logan River, measurements of... 146, 15
Long Pine River, measurement of.....
Long Swamp Creek, measurement of ...
Lord, H. S., work of .....
Los Angeles River, measurements of. 19
Los Pinos River, measurements of .....
Loup River, measurements of.....
Lovell, Wyo., hydrographic work at ....
Lozier, Tex., hydrographic work near. 11
Lyons, Colo., hydrographic work at.. 77
Lytle Creek, measurements of .....
McDonald, Wash., hydrographic work a
McDowell, Ariz., hydrographic work at . 140-14
Macon, Ga., hydrographic work at ... 32
Madison, S. C., hydrographic work at. 28
Madison River, measurements of..... 68
Maine, hydrographic work in.....
Malad River, measurements of... 155, 16
Mancos, Colo., hydrographic work at ... 13
Mancos River, measurements of.. 131, 13
Manhattan, Kans., hydrographic work at

Page.
b., hydrographic work at... 108, 112, 116
mal, measurements of. 119, 125, 130
. hydrographic work at..... 77, 82, 86, 89
ographic work in 10, 17-19, 21, 23-25, 59, 61, 65
Nev., hydrographic work at. 146, 148-149, 153, 154
work of 142, 143
measurements of 66, 67, 68
hydrographic work near.... 143
ydrographic work at.... 66-67, 68
easurements of..... 68, 70, 74, 75
ver, measurements of 88
asurements of..... 68-69, 72, 75, 76
urements of 189, 192, 195
y 146, 153, 155, 168
, hydrographic work at ... 10, 20, 23, 24, 25
ydrographic work at..... 48, 56, 57, 58
iver, measurements of 88
hydrographic work at.. 156-157, 163, 168, 169, 170
measurements of..... 156-157, 163, 169, 170
measurements of.... 68, 72, 75, 76
y 9
drographic work at..... 179
ographic work at .. 47, 49, 57, 58
ydrographic work at..... 25-26, 35, 44
er measurements of... 10, 21, 24, 25
ographic work in..... 68-76, 155-157, 163, 168-170
daho, hydrographic work at. 155, 160, 168, 169
dhographic work at... 159, 167, 169
., hydrographic work at.. 77, 81, 86
aid by 8, 95, 116
hydrographic work at..... 60, 64, 65, 66
aid by 8, 44, 45, 65
measurements of..... 158, 164, 170
drographic work at ... 25, 33, 44, 45
rographic work in..... 69, 76, 78, 86, 81, 85-88, 95
measurements of.. 110, 115, 116, 117
hydrographic work at..... 108, 112, 116, 117
measurements of..... 25, 34, 44
graphic work in... 145-149, 153, 154
s, Tex., hydrographic work 119, 124, 129, 130
ydrographic work in... 9, 16, 23, 24
ydrographic work in. 120, 127-130
asurements of 59, 61, 62, 65
letters of transmittal by.... 6, 106
, aid by 188
ydrographic work at.. 90, 92, 95, 96
measurements of..... 69, 88
id by 171
, hydrographic work at.. 78, 85, 87
River, measure- 24
, hydrographic work in 25-27, 33-37, 44, 45, 59, 62-66
River, measurements of. 10, 22, 24
., hydrographic work at. 76, 81, 86, 88
River, measurements of..... 76, 78-81, 86, 88
irginia, measurements of. 10, 19, 25
, Wash., hydrographic work 158, 164, 170
ydrographic work at 177-178, 182, 185, 186, 193
hydrographic work at and 45, 47, 50, 57, 58
, measurements of ... 32, 43, 44, 46
measurements of..... 31, 43, 44, 46
, measurements of 10, 17, 23, 24
ydrographic work at..... 146, 151, 153, 154
measurements of.. 146, 151, 153, 154
phic work in..... 60 65-68
r, measurements of..... 60, 65

Page.
Olmstead, F. H., work of..... 185, 191, 192
Oostanaula River, measurements of.. 48, 52, 57, 58
Orchard, Colo., hydrographic work at..... 77-78, 84, 86, 89
Oreana, Nev., hydrographic work at..... 146, 148, 153, 154
Oregon, hydrographic work in..... 159, 167-169
Orin Junction, Wyo., hydrographic work at. 76, 79, 86, 88
Palmdale, Cal., hydrographic work at ... 186-187, 189, 190, 191
Palouse River, measurements of.. 155, 162, 168, 170
Parkinson, H. F., aid by..... 187
Patapsco River, measurements of.... 10, 18, 23, 24
Patuxent River, measurements of.... 10, 18, 23, 24
Paul, E. G., work of..... 23-24, 59, 65, 66
Pecos, Tex., hydrographic work near. 119, 125, 130
Pecos River, measurements of. 119-120, 125-126, 130
Pedee River, measurements of..... 26, 37, 44
Peko, Nev., hydrographic work at..... 143, 147, 153, 154
Pennsylvania, hydrographic work in..... 9, 17, 23, 24, 66
Platte River, measurements of..... 78, 85, 87, 88
Piedra River, measurements of.. 131, 139, 142, 145
Pocatello, Idaho, hydrographic work at.... 155, 159, 168, 169
Point of Rocks, Md., hydrographic work at. 10, 21, 25
Port Republic, Va., hydrographic work at. 10, 19-20, 25
Portneuf River, measurements of. 155, 159, 168, 169
Potomac River, measurements of.... 10, 21, 24, 25
Pressey, H. A., work of..... 60, 66, 67, 68
Preston, P. J., work of..... 108, 116
Proctor Creek, measurement of..... 45
Provo, Utah, hydrographic work at..... 146, 152, 153, 154
Provo River, measurements of... 146, 152, 153, 154
Pueblo, Colo., hydrographic work at..... 108, 111, 116, 117
Purgatory River, measurements of..... 108, 113, 116, 117
Queen Creek, measurements of..... 132-133
Quillayute, Wash., hydrographic work at.. 171, 175, 176
Radford, Va., hydrographic work at 59, 61, 65
Ranger, Wyo., hydrographic work at..... 131, 133, 144
Red Mountain, Cal., hydrographic work at..... 180, 184, 185, 186, 193
Redbluff, Mont., hydrographic work at.... 68, 71, 74, 75
Redbluff, N. Mex., hydrographic work at.. 130
Redlands Canal, measurement of..... 192
Republican River, measurements of..... 89-90, 91-92, 95, 96
Resaca, Ga., hydrographic work at.. 48, 52, 57, 58
Rhead, J. L., work of..... 146, 153
Rialto Canal, measurement of..... 192
Rio Grande, measurements of..... 120, 126-130
Rio Grande, N. Mex., hydrographic work at..... 120, 127, 129, 130
Riverside, Ala., hydrographic work near.. 48, 54, 57, 58
Riverside, Cal., hydrographic work near.. 192, 194, 195
Roanoke, Va., hydrographic work at. 25, 32, 44, 66
Roanoke River, measurements of.. 25, 32, 33, 44, 45
Rock Creek, measurements of..... 10, 22, 24
Rockhill, S. C., hydrographic work at..... 27, 38, 44, 45
Rocky Ford, Colo., hydrographic work at..... 108, 112, 116, 117
Rome, Ga., hydrographic work at ... 48, 53, 57, 58
Ross, C. P., work of..... 86
Rowlandsville, Md., hydrographic work at..... 10, 17, 23, 24
Rumford Falls, Me., hydrographic work at..... 9, 14-16
Russell, W. G., aid by..... 8, 95, 116
Sacramento River, measurements of 177, 182, 185, 186, 193
St. Vrain Creek, measurements of 77, 83, 86, 89
Salesville, Mont., hydrographic work at... 68, 69, 74, 75
Salida, Colo., hydrographic work at 107, 110, 116, 117

Page.
Salina, Kans., hydrographic work at. 90, 93, 95, 96
Saline River, measurements of..... 90, 93, 95, 96
Salisbury, N. C., hydrographic work at.. 25, 36, 44
Salt River, measurements of..... 133, 140, 143, 145
Saluda River, measurements of..... 28, 39, 44, 46
San Antonio River, California, measurements of..... 196
San Antonio River, Texas, measurements of..... 130
San Felipe River, measurement of..... 130
San Francisquito Creek, measurement of.. 196
San Gabriel River, measurements of.... 187-188, 189, 190-191, 192, 196
San Joaquin River, measurements of.... 179-180, 183, 185, 186, 193
San Juan River, measurements of..... 131, 138, 142, 143, 145
San Marcial, N. Mex., hydrographic work at..... 120, 128, 129, 130
San Marcos River, measurement of..... 130
San Miguel River, measurements of..... 131, 137, 142, 144
Sandusky River, measurements of..... 66-67, 68
Santa Ana Canal, measurements of 191, 192
Santa Ana River, measurements of..... 188-189, 190, 191, 192, 194-195
Santa Clara River, measurements of 196
Sappington, Mont., hydrographic work at.. 68, 71, 74-75
Savannah River, measurements of 28-31, 40-42, 44, 46
Scioto River, measurements of 60, 65
Seattle, Wash., hydrographic work near ... 171, 172-173
Seguin, Wash., hydrographic work at 171, 174, 176
Selma, N. C., hydrographic work at 25, 34, 44
Sespe River, measurements of..... 196
Sharpsburg, Md., hydrographic work at.... 10, 19, 23, 24
Shenandoah River, measurements of 10, 20, 23, 24, 25
Shirley, F. S., aid by 8, 153, 155, 168
Shoshone River, measurements of..... 69, 73, 76
Slater, Colo., hydrographic work at 143
Smith, F. D., work of..... 168
Smith, G. E., aid by 8, 87-88, 95
Smoky Hill River, measurements of.. 90, 93, 95, 96
Snake River, Colorado, measurement of 143
Snake River, Idaho, measurements of 155, 160, 168, 169
Soda Springs, Idaho, hydrographic work at. 146 149, 153, 154
Solduck River, measurements of 171, 175, 176
Solomon River, measurements of..... 90, 92, 95, 96
South Boulder Creek, measurements of 77, 82, 86, 89
South Carolina, hydrographic work in..... 27-28, 38-40, 44-46
South Platte River, measurements of..... 77-78, 84, 86, 89
South River, measurements of 10, 20, 25
Spokane, Wash., hydrographic work at 159, 166, 169, 170
Spokane River, measurements of. 159, 166, 169, 170
Stanislaus River, measurements of 177-178, 182, 185, 186, 193
Staunton River, measurements of 25, 33, 44
Stinking Water River, measurement of 88
Stout, O. V. P., aid by..... 8, 87, 95
Superior, Nebr., hydrographic work at. 89-90, 91, 95
Susquehanna River, measurements of. 9, 17, 23, 24
Tallapoosa River, measurements of... 48, 56, 57, 58
Tar River, measurements of..... 25, 34, 44
Tarboro, N. C., hydrographic work at... 25, 34, 44
Taylor, L. H., aid by..... 8, 145, 153
Taylor, T. U., aid by..... 8, 118, 119, 129, 130
Tennessee, hydrographic work in.... 45, 60, 64-66
Tennessee River, measurements of... 60, 64, 65, 66
Texas, hydrographic work in.... 118-126, 128-130
Thomas, K. T., work of..... 44
Toccoa River, measurements of..... 60, 64, 65, 66

Page.
Toponis, Idaho, hydrographic work at..... 155, 160, 168, 169
Townsend, Mont., hydrographic work at.... 68, 72, 75, 76
Trinidad, Colo., hydrographic work at..... 108, 113, 116, 117
Trinity River, measurements of.. 118, 121, 129, 130
Trull, Colo., hydrographic work at..... 143
Tuckaseegee River, measurements of... 59, 63, 65
Tucker, Oreg., hydrographic work at.. 159, 168, 169
Tugalo River, measurements of..... 28, 40, 44, 46
Tulare Lake, measurement of..... 192
Tule River, measurement of..... 194
Tuolumne River, measurements of..... 178-179, 183, 185, 186, 193
Tuscaloosa, Ala., hydrographic work at.. 48, 56, 58
Uinta, Utah, hydrographic work at..... 146, 151, 153, 154
Umatilla River, measurements of..... 159, 167, 169, 170
Uncompahgre River, measurements of..... 131, 136, 142, 144
Union Gap, Washington, hydrographic work at..... 159, 165, 169, 170
Utah, hydrographic work in..... 131, 134, 143, 144, 146, 150-154
Utah Lake, measurements of 146, 152
Uva, Wyo., hydrographic work at.... 76, 78, 86, 88
Verde River, measurements of..... 133, 141, 143
Verdigris River, measurements of..... 109, 115, 116, 117
Vickerys Creek, measurement of..... 45
Virginia, hydrographic work in 10, 19-20, 22, 24, 25, 32, 33, 44, 59, 61, 65, 66
Vogleson, J. A., work of..... 191
Waco, Tex., hydrographic work at... 118, 121, 129
Wallawalla River, measurements of 159, 166
Ware, W. J., aid by..... 8, 171
Warmsprings, Cal., hydrographic work at. 188-191
Washington, hydrographic work in 155, 157-159, 162-166, 168-170
Washington, D. C., hydrographic work at. 10, 22, 24
Waterloo, S. C., hydrographic work at..... 28, 39, 44, 46
Waterville, Me., hydrographic work at... 9, 11-14
Waterville, Ohio, hydrographic work at. 66, 67, 68
Weber River, measurements of.. 146, 151, 153, 154
Weiser, Idaho, hydrographic work at..... 155, 162, 168, 170
Weiser River, measurements of.. 155, 162, 168, 170
West Gallatin River, measurements of..... 68, 69, 74, 75
West Point, Ga., hydrographic work at ... 47, 51, 57, 58
West Virginia, hydrographic work in 10, 20, 23-25, 59, 61, 62, 65
Wetumpka, Ala., hydrographic work near. 48, 55
White River, Colorado, measurement of.... 143
White River, Nebraska, measurements of.. 88
Whitewater River, measurement of..... 196
Whitman, Wash., hydrographic work at. 159, 166
Wiley, A. J., aid by 155
Williams River, measurement of..... 143
Willis, R. H., work of..... 86
Wills Creek, measurements of..... 24
Woods Landing, Wyo., hydrographic work at..... 76, 78, 86, 88
Woodstock, Md., hydrographic work at.... 10, 18, 23, 24
Wyoming, hydrographic work in..... 69, 73-74, 76, 78, 79, 86, 88, 131, 133, 134, 140, 142, 143
Yadkin River, measurements of..... 26, 36-37, 44
Yakima River, measurements of. 159, 165, 169, 170
Yampa River, measurements of..... 143
Yeates, W. S., aid by 8
Yellow River, measurements of..... 31-32
Yellowstone River, measurements of.... 69, 73, 76
Youghiogheny River, measurements of.... 59, 61, 65, 66
Yuba River, measurement of..... 193
Yuma, Ariz., hydrographic work of..... 133, 141

DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

RRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 29

WASHINGTON
GOVERNMENT PRINTING OFFICE
1899

J. C. Branner.

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

WELLS AND WINDMILLS

IN

NEBRASKA

BY

ERWIN HINCKLEY BARBOUR

WASHINGTON

GOVERNMENT PRINTING OFFICE

1899

CONTENTS.

	Page.
tter of transmittal	11
portance of water resources	13
tion of water underground	14
Sheet water	17
Artesian water	18
Conservation of soil moisture	24
Pollution of water	26
Surface and seepage water	27
Fluctuations of water level	28
thods of raising water	28
Homemade windmills	31
Cost	34
Classification	34
Distribution	35
Jumbo windmills	35
Baby jumbo windmills	37
Jumbo windmills of intermediate size	38
Screw jumbo windmills	41
Construction of jumbo windmills	42
Pumps	44
Merry-go-round windmills	44
Open-faced or turbine windmills	47
Battle-ax windmills	47
Holland windmills	54
Towerless turbines	56
Stationary turbines	56
Vaneless automatic turbines	59
Giant turbines	60
Reconstruction of windmills	64
Shopmade turbines	65
Original uses for shopmade windmills	66
Other forms of water lifters	67
ansmission and storage of windmill power	69
ecipitation in Nebraska	71
rface water available for irrigation	73
pply for towns and cities	73
lt water	75
owing wells	78
lex	83

ILLUSTRATIONS.

Page.

PLATE I. *A*, Riverview Park artesian well, near Omaha; *B*, Artesian well in Holt County 18

II. *A*, Artesian well at Beaver Crossing; *B*, Well of T. M. Ferguson at Beaver Crossing 24

III. *A*, Platte River, near Gering; *B*, Dam at Milford 28

IV. *A*, Windmill and tower; *B*, Experimental windmill at farm of University of Nebraska 30

V. *A*, Baby jumbo windmill on Goodrich farm, near Bethany, Nebraska; *B*, Baby jumbo built by J. L. Brown, Kearney, Nebraska 36

VI. Mounted jumbo windmill on Goodrich farm, near Bethany, Nebraska 36

VII. *A*, Medium-sized jumbo windmill in garden of M. J. Olson, Cozad, Nebraska; *B*, Large jumbo windmill at Cushman Park Gardens, Lancaster County, Nebraska 38

VIII. *A*, Jumbo windmill in Travis gardens, near Lincoln, Nebraska; *B*, Screw jumbo windmill 38

IX. *A*, Method of attaching arms of jumbo windmill to axis; *B*, Another method of attaching arms of jumbo windmill to axis 40

X. *A*, Method of construction of six-fan jumbo windmill cross-braced by twisted wire; *B*, Method of construction of eight-fan jumbo windmill 40

XI. *A*, Method of construction of gangs of jumbo windmills of a diameter of from 12 to 14 or more feet and of indefinite length; *B*, Method of construction of screw jumbo windmills with canvas sails and arms braced with twisted wire 42

XII. *A*, Gang of jumbo windmills erected above corncribs or sheds; Jumbo windmill with wind guard or cut-off 42

XIII. Small mounted merry-go-round windmill near Lincoln, Nebraska. 44

XIV. *A*, Merry-go-round windmill built by S. S. Videtto, Lincoln, Nebraska; *B*, Suggested form for eight-fan merry-go-round windmill 46

XV. *A*, Battle-ax windmill on farm of Matthew Wilson, near Overton, Nebraska; *B*, Battle-ax windmill on farm of Fred Woulf, near Grand Island, Nebraska 48

XVI. *A*, Six-fan battle-ax windmill of John Harders, near Grand Island, Nebraska; *B*, Eight-fan battle-ax windmill of Diedtrich Huennecke, near Grand Island, Nebraska 50

XVII. *A*, Giant battle-ax windmills on farm of J. S. Peckham, near Gothenburg, Nebraska; *B*, Two-fan battle-ax windmill built by Elmer Jasperson, Ashland, Nebraska 52

P

PLATE XVIII. *A*, Dutch windmill of August Prinz, near Chalco, Nebraska; *B*, Six-fan Dutch windmill of Henry Bormann, near Portal, Nebraska

XIX. *A*, Four-fan stationary turbine mill of Friederich Ernstmeyer, near Grand Island, Nebraska; *B*, Six-fan stationary turbine of Fred Mathiesen, near Grand Island, Nebraska

XX. *A*, Giant turbine built by J. M. Warner, near Overton, Nebraska; *B*, Four-fan geared turbine built by Henry Boersen, near Grand Island, Nebraska

XXI. *A*, Reconstructed windmill of E. M. Searles, jr., at Ogallala, Nebraska; *B*, Irrigating pond and reconstructed windmill on farm of Elmer Jasperson, near Ashland, Nebraska

XXII. *A*, Railroad water tank and windmill; *B*, Elevated tanks filled by windmill for town supply, used at Fairmont, Fillmore County, Nebraska

XXIII. Ponds of the Moulton Ice Company, Lincoln, Nebraska, supplied with water by two turbine windmills

XXIV. Windmill and water elevator on Blue River, near Milford, Nebraska

XXV. *A*, Thirty-foot current water wheel on branch of Hat Creek, Sioux County, Nebraska; *B*, thirty-five foot current water wheel near Hot Springs, South Dakota

XXVI. Waterworks at Kearney, Nebraska

XXVII. Burlington Beach, near Lincoln, Nebraska

FIG. 1. Course of water percolating from surface of soil down to saturated area

2. Inclined water table on eroded rocky floor

3. Open windlass and well curb

4. Partly inclosed windlass and well curb

5. Jumbo windmill of M. J. Olson, Cozad, Nebraska

6. Jumbo windmills and reservoirs in the market gardens of Travis Bros., Lincoln, Nebraska

7. Break resulting from improper method of fastening jumbo windmill arms on the axis

8. Hooded merry-go-round built by William Winn, Berwin, Nebraska, showing semicircular hood on rollers guided by large rudder

9. Plan of hooded merry-go-round windmill built by William Winn

10. Plan of large merry-go-round windmill of E. E. Blackman

11. Details of construction of battle-ax windmills

12. Working parts of the four-fan battle-ax windmill on the farm of Matthew Wilson, Overton, Nebraska

13. Method of construction of the battle-ax mill of Fred Woulf, near Grand Island, Nebraska

14. Working parts of the eight-fan battle-ax windmill of Diedtrich Huennecke, near Grand Island, Nebraska, with one fan in position

15. Battle-ax windmill driving crosscut saw, built by A. G. Tingley, Verdon, Nebraska

16. Stationary turbine designed and built by Janak Bros., Sarpy Mills, Nebraska

17. Sketch of homemade steel turbine of W. F. Baldwin, Ainsworth, Nebraska

Page.

FIG. 18. Method of regulating the fans of the homemade steel turbine of W. F. Baldwin 60
19. Method of construction of four-fan turbine mill of Henry Boersen, near Grand Island, Nebraska 61
20. Homemade turbine mill of Lewis Jardee, of Newport, Nebraska 62
21. Side view and details of revolving parts of homemade turbine windmill of W. F. McComb, Grand Island, Nebraska 63
22. Two-foot tympanum water wheel operated by 12-foot aermotor 67
23. Transmission of power of windmill by oscillating wires 70
24. Monthly precipitation in Nebraska 71
25. Plan of waterworks at Kearney, Nebraska 74

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, February 15, 1899.

SIR: I have the honor to transmit herewith a manuscript entitled "Wells and Windmills in Nebraska," prepared by Erwin Hinckley Barbour, professor of geology in the University of Nebraska and acting State geologist. The data for this manuscript were obtained by Professor Barbour incidental to his studies of the geology of the State, and have been rounded out by special work carried on under his direction. The original manuscript as prepared consisted of two parts—the first upon wells, and the second upon homemade windmills—but owing to delays in printing the first part, it has been considered advisable to combine the two papers into one and thus secure earlier publication. The manuscript as thus combined is offered as one of the water-supply and irrigation papers.

In the earlier numbers of this series considerable space has been given to the subject of windmills and discussions of the results obtained by experiments. These facts have been presented in the hope of stimulating the development of more economical and efficient methods of raising water for irrigation. In the present paper another phase of the matter is presented, and it is shown that by the use of material at hand a thrifty and ingenious farmer can produce results worthy of imitation. It is not to be supposed that homemade devices will be as efficient as those made for competition in the open market, but in the country, far from centers of population, it is not always practicable for the farmer to obtain such machinery. Lack of ready money and difficulty of transportation may prevent his obtaining the best windmill or pump. Under these conditions it is infinitely better for him to use the means at hand rather than go without. It has been shown by Professor Barbour that where one man in a community invents and builds a useful device of this kind others are quick to imitate, so that one homemade windmill or pump is copied on neighboring farms for miles around.

It is pointed out in this paper that the homemade windmill is not necessarily a contrivance incident to poverty or hardship. Many of the mills of this kind have been made by men who might afford to

buy shopmade mills, but who, having sufficient ingenuity and pos sing the necessary materials, have preferred to combine these produce effective machinery. They have merely exercised in direction the thrift whose existence is shown by countless other tok about their farms. The homemade windmill must not, therefore, considered an indication of poverty, but rather the reverse, sinc is usually accompanied by progress in all lines.

The subject matter of this paper is related to water conservatio the small way. Throughout the Great Plains region the suppl water is so scanty and so widely disseminated that as a rule it be impracticable to provide great storage reservoirs or other work considerable magnitude. On the other hand, for the utilizatio the resources there must be innumerable attempts to employ small amount of water almost everywhere available; and this ca done most economically through the use of the ever-present fore the wind. Thus windmills throughout at least one-fourth of United States must ever be inseparably connected with the utiliza of wells and with the development of the country.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charg

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

NELLS AND WINDMILLS IN NEBRASKA.[1]

By Erwin Hinckley Barbour.

IMPORTANCE OF WATER RESOURCES.

Nebraska, as in other portions of the Great Plains region, the ipal source of wealth lies in the soil. The fertility of this section rvelous and agricultural possibilities are such that subsistence be obtained for a population of several millions; yet this domain r the most part sparsely populated, the progress of settlement been checked, and the tilled areas are increasing in extent but ly. This apparent cessation of progress during 1894, 1895, and , especially in the western half of the State, is due mainly to one e, the insufficiency of rainfall.

xcept the soil and its products, the natural resources of Nebraska few. The consolidated rocks are deeply buried beneath clays, ds, and gravels; there are few, if any, minerals of commercial ue, no beds of coal nor veins of ore, no fields of gas nor oil, but er, owing to its comparative scarcity and its importance in agritural economy, rises to the rank of a mineral resource of the great-importance. The development and employment of all of the sup- flowing on the surface or percolating underground necessitates a dy as thorough as that given by other States to coal, iron, or cious metals.

This paper has been prepared as a preliminary study of the water blem in Nebraska. In it the attempt is made to review briefly the neral subject of the water supply, to bring together the more obvious ts, and to state these so that they may be understood by the farmer citizen not skilled in technical or scientific practice. The facts which the paper is based were gained in part by personal obsertion, and were supplemented by correspondence carried on by inted schedules and letters. The discussion is general in character, ating of the behavior of water underground, and particularly of e methods of bringing it to the surface for domestic use and for use agriculture. Reference is also made to the surface waters of the

Notes and data respecting wells have been brought down to the spring of 1897; those respect- windmills to the spring of 1899.

State and the amount of rainfall, some facts are given concerning the salt or saline waters and their utilization, and the peculiar blowing or breathing wells are briefly described.

ACTION OF WATER UNDERGROUND.

Air, which is the vehicle for moisture, can carry a greater load when it is dry, warm, and in motion. If the air is cooled, it can no longer carry its burden, which is dropped from the clouds as rain. Follow the course of the raindrops, or the circulating water, as it is aptly called, from the moment of impact with the surface and it will be seen that (1) a portion runs off, washing eastern soils badly, but washing western less; (2) a portion soaks in, since the soil is sandy, as it does not in clay soil; (3) a portion is evaporated, the average annual evaporation in Nebraska amounting to 4 or 5 feet; and (4) a portion, insignificant in amount, is taken up by plants and animals.

The portion that soaks into the soil sinks by its own weight deeper and deeper through the capillary or hair-like passageways and is lost

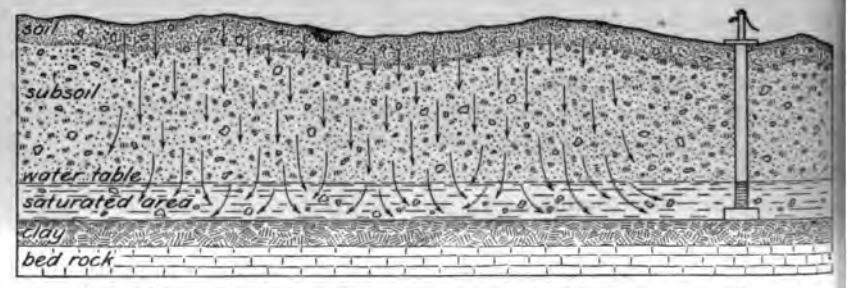


FIG. 1.—Course of water percolating from surface of soil down to saturated area.

to sight. It is universal experience that the soft, permeable surface material may change below to harder or even impermeable layers. Then it is that the water in its downward course is turned aside to flow laterally in all directions. Friction, however, greatly retards its movement. Constant additions are received as the rains continue, so that the creeping waters pile up, as it were, and gradually rise higher and higher; that is, the water table or water plane is rising.

As the process continues the creeping layer must rise to or near the surface of the soil, and thus the ground becomes water-logged—that is, soaked or saturated with water. (See fig. 1.) At such times springs are flowing, the ponds and streams fed by them are full, wells are inexhaustible, and vegetation is luxuriant and continues so during dry weather or even moderate drought. Let the season of drought continue and the creeping waters eventually steal away, and the saturated area is reduced to nothing; that is, the water table is settling. At such times ponds, springs, wells, and streams may fail—the more superficial first, the deeper last. Fresh showers cause them slowly to *rise again,* or perhaps they may rise without precipitation by acces-

ons of water at some more remote spot, or from the seepage of some ver swollen by floods at its source. Or, in still a third case, they ay rise in an apparently mysterious manner without the interven-on of showers or flood, simply because of hydrostatic connection ith some other region which is flooded.

The water table, then, is subject to rise and fall because of water eceived at home or from abroad. It is not an entirely stable body reserving a constant level, but is subject to seasonal variations and ariations incident to cycles of dry and wet years. The water table i not necessarily level, but is usually so, for instead of following the ocky floor the water table may run parallel with the surface. The loor, as well as the surface, is apt to be undulatory and the water lane or table higher or lower, according to the material passed hrough, to the escape of the water, and to other modifying causes. See fig. 2.)

The ground water or free water, as it may be called, is evidently in rculation and subject to fluctuation. The wells of the region like-ise vary, although this is scarcely worthy of mention in the case of ebraska, from the fact that nearly all of the counties report an unlim-

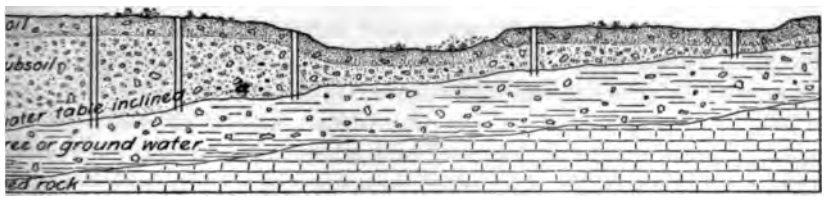


FIG. 2.—Inclined water table on eroded rocky floor.

ed water supply, with inexhaustible wells. When the water table ses to within half a yard of the surface, vegetation suffers or is rowned out. On the other hand, when the water settles too far, lants may suffer equally from lack of water to carry soluble plant ood to their roots and rootlets. When, however, the water table ands at a mean level between these two extremes, the fields of the tate, with an annual rainfall of but 23.3 to 25 inches, produce crops nd withstand droughts in a manner astonishing to the citizens of egions possessing double the annual precipitation. At first it seemed ncredible that such magnificent yields could come from so insignifi-ant a rainfall. Nevertheless the fact stands. There are two appar-nt reasons for this. The rainfall in many eastern regions amounts o 35 or 40 inches, but one-half is lost by running off and carrying ith it valuable soil fertility, the other half soaking into the ground, hile in Nebraska the water lost as run-off is only about one-tenth. lence, here a far greater proportion of storm water is stored for uture use. This is largely due to the sandy nature of the soil. Even ome of the so-called clay soils, though looking and acting like clay, re in fact exceedingly fine sand.

From the mechanical analyses of soils and subsoils made thus far it is shown that Nebraska soils are peculiarly rich in sands and poor in clays. The amount of sand—including in this term coarse, medium, and fine sand and silt—runs as high as 97 to 98 per cent. The lowest percentage thus far is about 66 per cent, while the average is probably about 78 per cent, based on the analyses made by Prof. Milton Whitney, of the Department of Agriculture. In a word, there is a preponderance of sand in Nebraska soils, which renders them at once light and capable of readily imbibing a larger proportion of rainfall than is possible in eastern States. This is a very significant fact.

The more one cultivates the virgin prairie, which when hard packed sheds water like a roof, the greater will be the amount of storm water caught and stored in the soil and the less the run-off and evaporation. Increased cultivation tends toward the conservation of soil moisture, and this in turn reacts, making it possible to catch more moisture, since soil already damp imbibes more rainfall than a dry soil. Thus as settlement goes on the amount of precipitation absorbed increases and the amount lost becomes even less. This statement must not be confounded with the popular but erroneous belief that the annual precipitation is increasing.

But when the spring rains cease and a season of settled weather or possibly drought sets in, and the surface soil dries, a force of great interest and of profoundest importance begins to act. This force is capillarity, by virtue of which water is drawn up through the minute, hair-like passageways of the soil and subsoil, rising automatically as much as 6 or 7 feet. This, then, is a second way by which water is held in the soil, and its far-reaching importance is instantly apparent when one considers that the very passageways up which this water is drawn are those down which rootlets grow. Soil moisture laden with soluble plant food is thus carried up to the rootlets or feeders of growing vegetation. Crops and grasses are nourished by capillary water and saved by it uninjured in time of drought, even during seasons of long-protracted dryness (if not accompanied by hot winds), such as could not but blight crops and grasses elsewhere. However, it is not to be forgotten that this force works equally well both ways, thereby carrying moisture up or down, according as the surface soil or the deep subsoil is the drier. This only emphasizes the importance of utilizing all available rainfall in saturating the deeper soil as completely as possible, in order that the full energy of capillary attraction may be expended in drawing soil moisture to the rootlets.

Thus far two means have been considered by which water is held by the soil—first, as ground water, sinking by gravity, and, second, as capillary water. There is another means so subtle and concealed as to merit little more than passing notice—hygroscopic water, which is *inherent* in many minerals, rocks, soils, and substances, and may be *obtained by long-continued* roasting.

SHEET WATER.

There is in common parlance a rather indefinite and puzzling use the terms, first, second, and third water, and sheet water. By first ter is meant the first surface water that seeps into the well; a supply en weak and readily exhausted. By second or sheet water, as it is mmonly called, is understood the deeper ground water, which is imited in amount, since it is contained in porous material that vers water rapidly. Third water, as the term is popularly used, oubtless the same second water struck at a lower level, after passthrough a local layer of fine material of slow delivery.

heet water is a greatly abused term, about which has gathered e impressions not easily dispelled. It carries with it wherever l the idea of subterranean water, flowing at an exaggerated rate er the ground. It is perfectly true that ground water flows and t it has certain channels, naturally decided by the coarseness or ness of the material, but one hears repeatedly of well diggers king subterranean currents of sheet water flowing at the apparly incredible rate of 4 or 5 miles an hour, a faster rate than that the Platte itself. This fallacious statement is made repeatedly in sincerity and good faith. A very popular conception of this tortial sheet water is that it is the angry and pent-up floods of subranean caves, which are seeking outlets to the sea. This erroneous ception is worse than fallacious; it is entirely misleading.

here is no such current in the sheet water, and there are no such ensive caves and underground lakes, and can not be in the sandy l of Nebraska. Caves are formed in limestones, not in sands, for urally the sand would cave in and fill any great underground sageways as fast as formed. This misconception comes about urally enough in some cases, and is cherished with a faith not to shaken. The well digger, who, while bailing or pumping out the ter on one side of the well, sees water flowing in from the other, l tell without hesitation in which direction the water flows, for he as seen it himself;" but let him set his pump on the opposite side the well and the current will set in from the other direction.

)f course there is a current whose rate is regulated by the coarses or the fineness of the material through which it flows, but this ne current is inconceivably slow. Coarse material with rapid ivery of water may have a current as slow as a fraction of a foot ay, or as rapid as several feet a day, while in fine-grained, compact l the rate is reduced to little or nothing. A better understanding the power of delivery of various materials would correct many of se errors.

f an old pail or keg, having holes in the bottom, is filled with clean, rse pebbles, and a stream of water poured in, the rate of delivery)ractically as rapid as the rate at which the water is poured. Its e is so *rapid that the water* flows down through the gravel in a

column, scarcely wetting the other pebbles. With the sand, however the water spreads out or is diffused through much or all of the mass and is delivered slowly at the bottom. In the silt, which is impalpabl fine sand, the rate is still slower and the whole mass is saturated wit water. In clay—the fineness of which is extreme—there is no deliver at all in experiment and practically none in nature. Mix togethe gravel, sand, silt, and clay, about as they occur in nature, and th rate becomes about the same as that of the finest material—that is water is delivered with extreme slowness.

This set of experiments tends to show the rate at which water ca flow through soil or rock of various degrees of porosity, and disprove the statement that the velocity of underground currents is in any wa comparable with that of surface streams.

ARTESIAN WATER.

Ground water is almost universal and is the source of the suppl of common wells. In addition to this there is the extraordinar subterranean water which supplies artesian wells. In the commo house well the water seeps in and stands quietly at a certain leve In the artesian well it comes in under pressure. This is the on essential difference between the two. The artesian wells in Artoi France, from which the name "artesian" is derived, were the fir dug and observed. These were spouting wells from deep source hence the term artesian presupposes in the public mind a spoutin well from deep-seated sources.

This early conception, however, is not the true one. Many art sian wells are shallow, not over 60 to 80 feet in depth, but yet a true artesian wells. Many throw fine streams from a few inches t several feet high, and are unquestionably artesian wells; but a sho distance away at a higher level the same water will rise in the we under the same pressure and is likewise artesian, even though th head is not sufficient to force it above the surface. The one is a active, positive, flowing artesian well; the other a negative, passive or standing artesian well.

In Johnson and Seward counties the shallow artesian wells ar beautifully represented. They occur in valleys where the surfac has been washed away and lowered, thus enabling the pressure o "head" to force the water above the surface 10 to 12 feet. On thi level flowing wells are everywhere to be found, which are already pu to many economic uses, and farms which are models of their kin draw their water for irrigation from this source with no cost. Thes are positive or flowing artesian wells. On farms a few feet highe precisely the same water is struck. It rises to the surface, but ca not flow over it.

It is universal experience that rocks, some soft and porous, son dense, are found in the State arranged in horizontal beds. The dens

A RIVERVIEW PARK ARTESIAN WELL, NEAR OMAHA, NEBRASKA

Depth, 1,060 feet; capacity, 114,427 gallons a day; 6-inch pipe; water but slightly saline; temperature, 62°; cost, $1,000. This well supplies annually to the park system of Omaha a volume of water which, at the lowest wholesale city water rate, would cost $5,000 a year, and illustrates the use of artesian water for the beautifying of parks. In addition to the fountain and stream [illegible] supplied by the well.

B ARTESIAN WELL IN HOLT COUNTY, 14 MILES SOUTH OF O'NEILL ON THE FREMONT ELKHORN AND MISSOURI VALLEY RAILROAD.

will constitute the impervious jacket around the more porous . The layers which are deeply buried here, and but inappre- tipped, may come to the surface elsewhere and form a catch- basin, perhaps at a point far distant, as is the case presumably :he deeper wells found along the northern and northeastern ary of the State.

artesian wells, as far as reported, fall into four rather natural s, as follows: The deep wells of the Carboniferous, such as those ıtrice, Lincoln, and Omaha, varying from 556 to 2,463 feet; the ın wells of the Dakota sandstone, 300 to 400 feet deep, being tinuation into Nebraska of the South Dakota artesian basin; ıallow wells in glacial sands and clays, such as those at Cook, r Crossing, and elsewhere; and other shallow wells not in the such as those in Holt and Rock counties. (See Pl. I, *B*.)

re are local artesian basins in the State which are more easily ıssed than the deep wells. There are small basins of 10 to 15 ə miles each in the valleys of streams, depressed noticeably the general level of the surrounding hills. Within this circum- d area, wherever the impervious roofing or encasement of clay ced—the depth varying from 40 to 100 or more feet—there comes ng and constant flow. Such wells are too shallow to come from which draw their water supply from a distance, so that it is ıary to look for some other explanation.

ı at once apparent that this artesian supply is drawn from beds ırnating gravel, sand, and clay, deposited by glacial action dur- ıe ice age, and that it is rather limited and local, though none ıs important, as has been sufficiently demonstrated by its mul- ıus uses at Beaver Crossing and adjoining localities. Farther tream the wells, instead of growing stronger, grow weaker. s due to some leak or escape of the water through the imper- clay roof, which results in a reduction of head or pressure in all ınt wells.

alternating and confused arrangement of these beds comes naturally, because of the way in which the glacier and iceberg ted coarse, medium, and fine material together into heteroge- piles—clay here, sand there; sand, gravel, and pebbles else- . The porous gravelly layer, incased above and below by layers y, is not necessarily of uniform texture, but, instead, there among the coarser material patches or islands of finer material. ı as the well is in this patch or that, its head or pressure e accelerated, retarded, or stopped outright, according to the f delivery of water in coarse, fine, or clayey material. One at Cook, Johnson County, in the midst of flowing wells, has , and always must fail, to furnish artesian water, and there is ently nothing anomalous in the case. The farm is over what is a "clay island." All the wells dug on this farm penetrate clay and, *of course, one can not* hope to strike artesian water there.

List of artesian wells.

Name of well.	County.	Town.	Depth.	Remarks.	Ye
			Feet.		
Lincoln test well	Lancaster	Lincoln	2,463	6-inch pipe; throws water 5 feet above surface; salt water.	
Artesian well, Government square.	do	do	1,060	Bed rock at 95 feet; salt water 160 feet; first flow 560 feet.	
Sulpho-saline bath	do	do	556	Strong flow; salt water; 100,000 gallons per day.	
David Swaney	do	5 miles west of Lincoln.	240	Slight flow	
Willow Springs distillery or Iler's well.	Douglas	Omaha	1,700 to 1,800	First flow at 700 feet; second flow at 1,700 feet; pressure 37 pounds per square inch; used for boiler.	
Pickard's or "Well No. 1."	do	6 miles west of Omaha.	1,383	Heavy flow at 517 feet, 676 feet, and 894 feet; strongest flow at 1,080 feet; pressure 150 pounds.	
Courtland Beach or Cut-off Lake well.	do	3 miles northeast of Omaha.[a]	998	6-inch pipe; throws water 40 feet; 86,000 gallons per day.	
Riverview Park well.	do	2 miles south of Omaha.	1,064	4-inch pipe; 114,427 gallons per day; slightly saline. Feeds a lake of 2 to 4 acres. Temperature, 62°.	
Omaha Packing Company.	do	South Omaha	1,800	Negative artesian, rising 70 feet to surface; strongly mineral. Temperature, 62°. Too warm for condensers.	
Elkhorn	do	Elkhorn	65	Soft water; cost, $45	
Lloyd Lunn	Adams	Near Hastings	114	6-inch pipe; cost, $31	
William Kearville	Boyd	T. 34, R. 8	760	Cost, $2,000; used for irrigation; 100 gallons per minute.	
Cal. Moffett	do	Sec. 2, T. 34, R. 12		Used for irrigation; 15 barrels per minute.	
G. L. Emmons	do	Sec. 18, T. 33, R. 8		Used for irrigation; 2,000 barrels per day; cost, $1,000.	
L. M. Short	Brown	5 miles from Ainsworth, in Sec. 9, T. 29, R. 22.	32	8-inch pipe; 40 gallons per minute; soft water; cost, $6. (?)	
C. W. Conkling	Burt	Tekamah	103	Three wells, 3, 4, and 8 inch, for city water supply.	
Craig	do	Craig	126	Flowing water at 120 feet. CO_2 blown off for several days.	

a Really in Iowa, because of meanderings of Missouri River.

List of artesian wells—Continued.

Name of well.	County.	Town.	Depth.	Remarks.	Year.
			Feet.		
A. E. Johnson	Cass	Weeping Water, sec. 16, T. 10, R. 12.	8	Ceased to flow, 1894	.....
Numerous wells	Cedar	.....	*a* 363	Average cost, $146; hard water.	.....
C. A. Johnson	Cherry	Woodlake, sec. 21, T. 31, R. 28.	100	Slight pressure; cost, $50; hard water; 100 gallons per hour; railroad well.	1892
A. Strong	do	Sec. 21, T. 31, R. 28.	17	Soft water	1892
R. A. Jones	Cheyenne	Near Sidney, sec. 20, T. 13, R. 45.	94	Negative artesian; cost, $75; by aid of pump. *b*	1886
J. E. Melcher	Cuming	Wisner	97	Used for irrigation; 2 barrels per minute; hard water; cost, $97.	1895
P. G. Cooper	Dawes	Crawford	86	12-inch stream, easily lowered; hard water; cost, $50.	.....
H. E. Grant	do	Sec. 25, T. 32, R. 52.	82	600 gallons per day; soft water; cost, $100.	1888
James Mozeller	do	Sec. 13, T. 32, R. 52.	18.5	2-inch pipe; soft water; good pressure until filled with sand.	1891
F. P. Ryan	Dixon	Ponca	407	60 gallons per minute	1885
Do	do	do	265	do	1894
Geo. Mattison	do	7 miles from Ponca.	484	Flowed three weeks and stopped; stands 6 feet below the surface; cost, $50.	1888
Fred Heine	Dodge	3 miles north of Hooper.	304	40 gallons per minute; hard water.	1892
Beatrice	Gage	Beatrice	1,260	Very salt; dug for city supply and abandoned; intermittent flow.	
J. J. Connoly	Garfield	Erina	110	Flows 6 feet above surface; soft water; cost, $11.	1894
P. A. McDonald	do	Sec. 15, T. 24, R. 14.	140	Soft water; constant flow; cost, $30.	1894
Benjamin Jones	do	Sec. 22, T. 24, R. 14.	175	3 feet above surface; soft water; 5 gallons per minute; cost, $37.	1894
A. J. Plumer	Grant	Hyannis, sec. 23, T. 25, R. 28.	450	4 gallons per minute; soft water; cost, $225.	1895
Numerous wells	Holt	.....	55 to 120	Soft water; average cost, $10 to $30.	.....
Edward De Merritt	Hooker	Mullen	.....	.....	.....
Herman Kracker	Johnson	4½ miles from Elk Creek, sec. 34, T. 4, R. 12.	146	Cost, $200	1894
J. J. Wilson (3 wells)	do	4 miles from Cook, sec. 1, T. 6, R. 10.	80	3 wells cost $90; fine soft water. *c*	1893

a Average depth.
b Used to water 2,000 sheep and to irrigate garden.
c *One well from 4-inch nozzle keeps* a 1-acre pond, 4 feet deep, full all the time.

List of artesian wells—Continued.

Name of well.	County.	Town.	Depth.	Remarks
			Feet.	
J. W. Holden	Johnson	4 miles from Cook, sec. 6, T. 6, R. 11.		Cost, $20
Many wells	Knox		504 to 770	Cost from $225 t majority hard
John Coker	Lincoln	9 miles from Sutherland, sec. 6, T. 14, R. 34.	22	Soft water; dou this is really a
Lew Williams	Logan	Gandy	81	Cost $80; soft a artesian well county; pip choked up; go sure.
Hy. Rainer	Loup	Taylor	80	Hard water
R. E. Haskell	McPherson	Lena	42	Cost $25; soft w gallons per mi
White Water ranch	do	Sec. 32, T. 20, R. 35.	30	Cost $15; 15 gall hour; soft wat
August Tannehill	Madison	6 miles from Norfolk, sec. 27, T. 25, R. 1.	125	Cost $90; 30 gall minute; mediu
E. D. Gool	Nance	8 miles from Fullerton, sec. 14, T. 17, R. 8.	28	Cost $100; says rises through gas pipe for 24
Geo. Young	Nemaha	2½ miles from Brock.	52	Cost $32; soft wa
J. G. Burriss	Otoe	¼ mile from Cook.	75	Cost $20; one ba minute; used gation; about wells in vicinit
Chas. Dorneau	do	4 miles from Unadilla, sec. 28, T. 9, R. 10.	282	Salt water; 30 per hour; cost
Capt. S. V. Moore	Pawnee	6 miles from Pawnee, sec. 8, T. 2, R. 11.	10	Cost $15; said to wet seasons; h cient water head of stock.
Will Patterson	do	3½ miles from Burchard, sec. 36, T. 2, R. 9.	85	Cost $85; unl amount of har slow flow, abou rels per day.
J. F. Wenzl	do	Steinauer, sec. 33, T. 3, R. 11.	11	Cost $40; flows in sons; soft wate
John McKenzie	Perkins	5 miles from Madrid, sec. 19, T. 10, R. 36.	150	Used for irrigati $150; soft wate
Many wells	Platte		12 to 100	Majority shallo from $50 to $100; and others sof
John Beckstrom	Polk	Stromsburg	104	Cost $75; unl amount of har

List of artesian wells—Continued

Name of well.	County.	Town.	Depth.	Remarks.	Year.
			Feet.		
Frank Nichols	Redwillow	McCook	405	Cost $200; oily water and weak flow, but flow has increased; experimental well.	1895
Many wells	Rock		95 to 143	Most costing from $30 to $40; all soft water.	.....
Dr. Geo. L. Miller	Sarpy	7 miles from Omaha, sec. 2, T. 14, R. 12.	1,430	Cost $5,000; pressure 15 pounds to square inch; soft water; fine artesian; supplies a 30-acre lake for ice and fish.	1891
Dr. Jos. Miller	Scotts Bluff	Gering	330	Cost $200; at first had a flow of 1,000 gallons per day, but filled up with sand and a pump is now used; soft water.	1894
Many wells	Seward		13 to 100	Used for irrigation; some hard and some soft water, ranging in cost from $18 to $85.	.....
Dr. S. Person	Stanton	8 miles from Pilger, sec. 6, T. 2, R. 3.	96	Used for irrigation; cost $77; hard water; declining flow, about 4 barrels per minute.	1895
R. C. Schwann	Valley	7 miles from Ord	70	Cost $52; soft water; 15 gallons per hour.	1893
William Fetch	Washington	Herman	76	Cost $75; soft water; good flow.	1897
William Rutledge	do	do	38	Cost $25; hard water; free flow.	1894
Solomon Sheets	do	do	37	Cost $25; hard water; 3 gallons per minute.	1894
Many wells	Wheeler		8 to 124	Cost from $8 to $75; all soft water.	.....
A. B. Codding	York	York	.....	Unfinished; cost $300; flowed 5½ hours, then 9 hours, and stopped; drill is fast in sand rock 600 feet deep. Water to be used in mill pond.	.....
Eugene Wright (two wells).	do	do	240, 590	Cost $200; power wanted for flour mill, but flow at 500 feet too weak.	1895
Harry Hill	Otoe	Palmyra	280	Salt water; 15 barrels per day.	.....

These local artesian wells are already turned to admirable account in supplying ponds for fish culture, fountains for school yards and parks, and water for domestic use and for irrigation. (See Pl. II, *A* and *B*.) The last-named use is destined to become of considerable economic

importance. Some farmers have already from eight to ten 5-inch wells per farm with which to irrigate over 100 acres each. The number who have tapped the subterranean reservoir and allowed the imprisoned water to escape and to flow away aimlessly and uselessly far exceeds those who have put it to intelligent use. There is enough artesian water wasted thus to irrigate whole farms. What renders this matter all the more deplorable is the obstinacy of many people in insisting that the supply can not be exhausted. This view is wholly fallacious, and if persisted in may result in damaging or destroying altogether an important resource. Every well dug must diminish the head or pressure that much, whether the amount is perceptible or not. Unrestricted abuse of these water privileges can but result disastrously here as elsewhere. All this water should be most conscientiously used and conserved.

In several localities, noticeably in Rock County, near Kirkwood, there are strong springs which boil up with such force that if the water be confined by placing several joints of old stovepipe in the throat of the spring the pressure is sufficient to force the water several feet above the surface. Springs of this kind are numerous, especially in this vicinity. Since the water rises under pressure, the name "artesian spring" is applicable. Similar springs in Johnson County are called "mound" springs, because the water in the center appears to boil up and is higher than that of the edge. This boiling occasionally gives them the name "kettle" springs. Such springs near Sterling are 30 feet across, and the overflow is reported as 3 feet wide and 2 feet deep.

CONSERVATION OF SOIL MOISTURE.

The importance of the conservation of moisture has not yet had the general recognition which the subject merits. But each year brings unmistakable advance in this matter, as is shown by the construction of new reservoirs and dams across streams and draws, and by new methods of cultivation. These are on the increase, and were it not for the difficulties in the way of making water-tight reservoirs in sandy soil and the large amount lost by evaporation (averaging 4½ feet for the State), greater progress might be reported. The matter of conservation of soil moisture by superior cultivation, being a less obvious factor, is lost sight of by many, and yet by this means there have been, to the author's knowledge, some marked examples of success, standing in strong contrast to the failure of others. By pulverizing to extreme fineness a coarse soil, the absorption of water may be increased a thousandfold. Compress or "firm" the soil, and the attraction of capillary water is increased to that extent. Mulch the surface into fine, loose particles, and the capillarity which draws the moisture up to the plant rootlets is broken at that point, and a

A. ARTESIAN WELL AT BEAVER CROSSING, SEWARD COUNTY, NEBRASKA.

B. WELL ON FARM OF T. M. FERGUSON, AT BEAVER CROSSING, NEBRASKA.

Depth to artesian water 80 to 90 feet. Height of pipe, 13 feet; diameter, 6 inches. Mr. Ferguson irrigates 112 acres from nine such wells which cost $900.

blanket is formed for the retardation of evaporation and retention of moisture in the soil. By careful and intelligent farming, wide areas now abandoned, or held by indifferent, roving classes, will prove to have ample moisture for agriculture.

The results of close and conscientious farming are astonishing. One aged English couple living near Lincoln were forced to undertake farming in a small way for subsistence. The land was poor and the season was bad. All the neighboring tenants fled, and earned nothing during the entire summer. The aged couple farmed all the more closely, conserving the soil moisture in every way known to them. Starting on nothing, and struggling through the most trying season recorded in the State, at the end of the harvest they deposited in bank $100 above their expenses, which they afterwards spent judiciously in purchasing stock and necessary machinery for another year. These are small earnings, but, nevertheless, the difference between their methods of farming and that of their nomadic neighbors is infinite. It is such farming as this that makes the agricultural reputation of a great State.

During a recent trying summer the agent of one of the railroad companies in Nebraska escorted several parties of Eastern capitalists across the State. Contrary to the advice of those who thought the course injudicious, the railroad company took the tourists through the least promising as well as the most promising parts of Nebraska. In the heart and center of a deserted region in the arid belt, where the cornfields on the right were withered and abandoned, they repeatedly came upon farms on the left with magnificent fields and the appearance of prosperity. They found, on inquiry, that the nomadic neighbors were in their "prairie schooners," seeking easier jobs elsewhere, while the colonists left behind were farming with extreme care and were prospering. On the one farm the finest crops were grown; across the road none at all. The difference was due solely to the farmers, the one farming carefully and conscientiously, the other slothfully. When arid lands respond in most unpropitious times to careful and intelligent treatment, what may not be expected of the best? Confidence in the future of agriculture in semiarid and arid Nebraska was impressed and fixed in the mind of each tourist who saw this admirable and striking example of the results of intelligent farming. Taking advantage of the lessons taught by superior cultivation, the Burlington and Missouri River Railroad Company has initiated a most commendable series of agricultural experiments in the semiarid and arid nonirrigated portions of Nebraska and Kansas. Here a practical test will be made of the actual utility of soil-culture methods for the conservation of moisture. Experiment stations have been established at Holdrege, Alma, Oxford, McCook, Curtis, Brokenbow, Grant, and Hastings, in Nebraska, and at Oberlin, Wheeler, St. Francis, and Bird City, in Kansas.

The method to be pursued is substantially that introduced at Putney, South Dakota, by Mr. H. W. Campbell as early as 1885, a method promising to be even more important than irrigation because of its wider applicability. This process consists essentially of deep plowing, subsequent firming of the soil to increase capillarity, and light surface cultivation to break capillarity and check evaporation, and to this end special machinery has been designed. The method is often known as "dust-blanket farming," the idea being to cut the surface into a soil mulch or powdery condition in order to prevent loss of moisture.

Farmers along the Republican River as far west as Harlan County who have tried this method find that a diversity of crops is possible, and that while the number of acres cultivated is reduced about one-half, the yield is increased several fold. For instance, potatoes, which yielded an average of 212 bushels under this treatment, gave but 25 bushels per acre to neighbors who avoided this system of close farming on the ground that it was expensive and onerous.

During the last five years various means for catching and holding surface water have increased enormously, and now attention is directed to the results consequent upon the better conservation of soil moisture, all of which will aid in the reclamation of important tracts of remarkably productive land now idle and unoccupied. There are table-lands 200 to 300 feet above water where no amount of conservation of moisture on the surface or in the soil can avail; but, on the other hand, there are countless regions to be benefited thereby. Such table-lands, therefore, where grazing is notably good, should be turned over to stock raisers, and the lowlands to agriculturists. Each class would prove of benefit to the other. Community life could be formed in the valleys and the uplands left for grazing.

It is universally conceded that cattle raising is profitable, and that the small herder can make steady gains by watching his cattle more closely instead of turning them loose upon the range as formerly. It is an easy way to turn stock upon the common range, where no care is required winter or summer except at the time of the annual "round up." But by that method the chances for loss are greater. Its day is past in Nebraska, and it is now time for many small cattle raisers to occupy the land once grazed over by the herds of great companies. The grazing lands should be turned to better account, the conditions of the valley lands should be better understood, and many important tracts now deserted should be reclaimed. This will come about by the storage of storm waters, by irrigation, and by the conservation of soil moisture.

POLLUTION OF WATER.

The water for domestic supply is well purified. In the river current the water is exposed to the air, and thus purification by the process of oxidation goes on. The ground water is likewise purified.

ut in its descent through the air, in its passage down the streams, or rough the soil and rocks, water, which is the universal solvent, takes certain acids and gases, and dissolves certain minerals, particularly me (making hard water), iron (making chalybeate water), potash soda (making alkali water), or salt (making saline water).

These are wholly inorganic ingredients and for the most part harmss. But there are other ingredients not to be detected by the sense smell, sight, or taste, which come from organic decay. Water in osely settled regions is subject to dangerous pollution. It then ecomes a vehicle for germs and contagious disease, and is not fit even r beasts. Wells should be so located and guarded that barnyard ash can not drain into them nor soak through the soil into them. he water filters through many feet of soil, and is pure and wholeme if proper precautions are observed. One may feel great confience in the purity and healthfulness of water drawn from a well hich passes through clay before striking water-bearing gravels.

The writer can not refrain from citing one specific case of wellater pollution. The occurrence of fever in three families in Omaha ointed unmistakably to the dairyman who supplied them with milk. n visiting the dairyman the city physician found three in his family uffering from the same fever. The seat of trouble seemed to be the ell, which was so injudiciously located as to receive surface wash irectly, and indirectly the offal from the house and barn, rendering e water at once nauseating and dangerous.

The cities of the State should zealously guard against the possible ntamination of their water. Good water for city use is so easily tained from groups or gangs of wells at reasonable depths that no mmunity seems justified in drawing its supply from surface streams, hich are subject to progressive deterioration as population increases.

SURFACE AND SEEPAGE WATER.

The marshes, ponds, lakes, and cut-off lakes are relatively few, and ed no further mention at present. The rivers, however, are of owing economic importance, and the time seems near when they ill be diverted from their channels into irrigating ditches. On this int many persist in cherishing the error that rivers can not be ained, maintaining that as rapidly as water is drawn off as much ore rushes in to supply the loss.

The Platte River flows east across the entire State, and is presumly of greater importance than the Missouri River. Though becomg entirely dry in certain seasons, the Platte nevertheless supplies portant areas with water for irrigation during the growing sea-n. More important than this is the underflow water of the Platte. is a singular and highly interesting river. Overloaded and taxed yond its power, it can not carry its burden of sand out of the State. cordingly its energy is spent in shifting its sand bars from side

to side and in forming a lace work of channels through its broad bed; but beyond this, it is receiving constant additions of fresh sand. Accordingly it has built up its bed with sand 50 to 200 feet or more. Through this alluvial material there is an underflow of broad extent on each side of the Platte throughout the State, which spreads out and constitutes in part the important underflow, or even some of the sheet water of the State. After the surface water of the Platte has been diverted for irrigation the underflow in its gravels can be drawn upon without limit if mechanical difficulties can be overcome. (See Pl. III, *A*.)

FLUCTUATIONS OF WATER LEVEL.

The years 1892, 1893, 1894, and 1895 were years of exceptional drought. The whole water table was lowered, and springs, ponds, streams, and many wells failed. During the winter of 1895 there was virtually no rain or snow. That is to say, there was no precipitation by which to account for an unexpected rise of water (apparently real) which began early in the winter, and reached a point in February and March which aroused general comment. Many, for the past three years, had knots tied in well ropes whereby the well buckets might be lowered each time into the shallow water without roiling it. It was soon noticed that the wells were filling unexpectedly, because the ropes were wet some 10 to 12 feet above the usual point. Water began to flow in channels hitherto entirely dry. The dry beds of ponds began to fill. Excavations for railroad embankments became lakelets. Springs which three years previously had supplied fish ponds, but had become dry, began to flow again; and damp spots began to appear in some farms. So many cases were reported in person or by letter that the author took pains to send out several thousand inquiries over the State. Two-thirds of those who answered had noticed an unexpected rise of water; one-third had not. The evidence is almost conclusive that this is real, and is a matter of annual occurrence.

One explanation is that the decreased evaporation and the increased cohesion of water in winter allows more ground water to accumulate. The majority reported the rise as occurring in February. Stockmen in the most arid portions of Nebraska depend implicitly upon this rise of water, which they assert is of annual occurrence, and independent of precipitation. This matter seems as worthy of critical study as any problem connected with our ground water.

METHODS OF RAISING WATER.

Peculiar and characteristic systems of hoisting water are found in vogue in widely separated counties. Some methods are very primitive and crude, while others show thought and ingenuity. It is very evident that the first simple windlass or pump put up in a community becomes the model after which others of precisely the same type are

A. VIEW DOWN NORTH PLATTE RIVER FROM THE WYOMING-NEBRASKA LINE

B. DAM ON THE BLUE RIVER AT MILFORD, SEWARD COUNTY, NEBRASKA.

;terned. Sometimes windlasses and pumps of communities, and ›n of towns, are built as if from one model, heedless of faulty ›ign and poor construction. Two forms are illustrated below. ›e figs. 3 and 4.) Occasionally one sees water drawn hand over nd by bucket and rope, but a much more common form, which is tually the same with the direction of motion changed, is the rope d pulley. Were it not that this method is laborious and slow, men ght draw water for stock and women for domestic use for years. it is, these are soon replaced by windlasses having a mechanical vantage. In the construction of these there is an occasional dis- ıy of thought, and one man will make one stick of timber answer ıere three, four, or five cks would have been used another. Others are elab- ıted until the cost exceeds ıt of a good pump. Many ›fer the open well and wind- s to pumps, on supposed ıitary grounds, assuming ıt the iron pipe is un- ılthful.

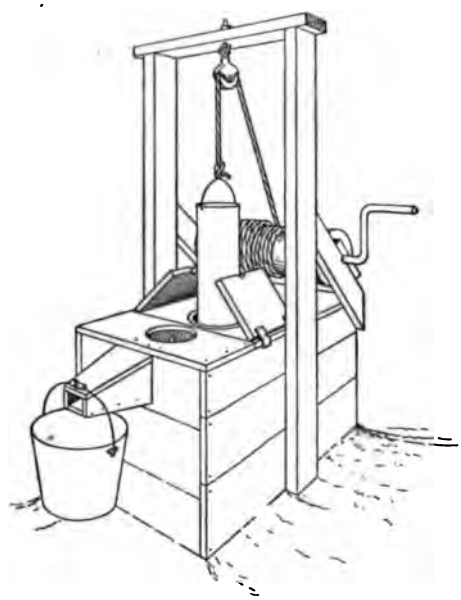


FIG. 3.—Open windlass and well curb.

:n regions of high table- ıds, where the wells are ›p, the labor of drawing ter, even by windlass, is ›h that hand power is re- ıced by horse power. Half rrels are used instead of ll buckets and a boy and rse can soon draw the water cessary for the family and ›ck. The author has seen › old-fashioned horsepower d tumbling shaft in use pumping water for the house and for igation.

The windmill has long been the popular means of raising water for mestic use and for watering stock, and now, in addition, it comes enjoy the recognition it deserves as one means of irrigating land ıere other means are wanting. It is the windmill which has ena- ›d the farmer to introduce into his home some of the modern conven- ıces of the city. Thus one finds farmhouses supplied with hot and ld water, with bath, lawn sprinklers, and fire protection, and that, ›, more cheaply than in a city home. The windmill feeds a steady 'eam of cold water through the milk house, and thence to the stock ugh, a matter so small as to be often forgotten, yet so large as to of great economic consequence. When the water around the milk

pans is cooled, a greater percentage of cream rises by gravity to the top. Where cool water is readily available the loss of cream may run low, but in less favored States where the water is naturally warm the loss may reach one-fifth. This, in a State whose butter products may amount to several million dollars annually, is a large sum. The difference of a single degree in the temperature of water in a State as large as Nebraska means a difference of thousands of dollars in the total dairy products. Here the windmill effects a great saving, and on well-regulated farms, while pumping water for the stock trough by way of the milk house, it may nearly pay for itself annually.

The windmill has replaced the town pump, and in villages and towns is now seen a sightly and well-kept mill and tank, supplying water to the public by the energy of the wind. (See Pl. IV, *A*.)

FIG. 4.—Partly inclosed windlass and well curb.

In supplying water for village use, pressure sufficient to throw water above the house tops may be had by placing the tank or reservoir upon high ground, or by erecting a suitable tower, which is the common method in the level prairie towns. Occasionally towers are built of exceptional height, to carry a second water tank for use in giving increased pressure in case of fire. (See Pl. XXII, *B*.)

The whirling mills are necessary accompaniments of Nebraska scenery. Their work is admirable, though impossible feats are often expected of them. As the matter of windmill irrigation is agitated the receptive mind of the progressive farmer seizes the idea. Not having experience and placing too confident reliance in the claim of the local agent, who is not a wholly disinterested party, he undertakes to raise water for irrigation from impossible depths. This must not be taken as a reflection upon the indispensable device, the windmill, which in many cases is as nearly perfect as skill can make it. The pump, not the windmill, is at fault; but the main trouble lies in the depth to water. Water can be pumped 32 feet. Below that point it must be forced, and from that point down mechanical loss increases at a rapid ratio. When one attempts to force a 60 or 70 foot column of water to the surface for irrigation his undertaking is barely within the limit of possible profit; below that point the enterprise is doubtful, if not dangerous. Farmers are urged to an immediate recogni-

A. WINDMILL AND TOWER. TOWN PUMP AT VERDON, NEBRASKA.

EXPERIMENTAL WINDMILL AND POND ON FARM OF THE UNIVERSITY OF NEBRASKA.

tion of the chances of discouragement, failure, and loss, resulting from any attempt to force water over 70 or 80 feet for irrigation, although this will undoubtedly be changed somewhat by improved pumping devices still to be invented.

At present every community in the State can furnish examples of misguided attempts to irrigate by means of water pumped by the wind from wells of unreasonable depth. This must not place in doubt or compromise in any degree the utility of windmill irrigation, which promises to become one of the important factors in the development of the agricultural resources of the State. Already farmers are irrigating with profit from 1-acre to 50-acre tracts by means of one or more windmills. Conversation and correspondence has brought out from many farmers in semiarid and arid Nebraska the plain avowal that during the exceptional season of drought, 1893–1895, the profits from the small patch irrigated by the windmill exceeded that from the rest of the farm.

HOMEMADE WINDMILLS.

Homemade mills are, of course, of low efficiency from a physical and mechanical standpoint; yet they are capable of doing all that is demanded and more. They cost little, wear well, and do all the work that is laid on them, so that it makes little practical difference whether some of them are mills of low or high efficiency. Of all the homemade mills which the writer has visited, he has yet to hear even a mild criticism offered against one by its owner.

What a contrast may be presented by two farms—one with cattle crowding around the well, waiting for some thoughtless farm hand to pump them their scant allowance of water, the other where the cattle are grazing and the tanks and troughs are full and running over to such an extent that the hogs have their wallows to which to resort in the heat of the day. Nowhere in his travels has the writer seen empty or dry troughs on farms where the homemade mill was found.

The windmill has an important effect on population. In many homes it is professedly the sole dependence, especially so with cattlemen living in regions where grazing is the very best and where the grasses are capable of sustaining great herds free of care or cost, summer and winter alike. The prerequisite is the irrigation of one acre on which to raise garden truck for the family, and this the windmill renders possible. Without this, emigration would result, and the State would lose not only important industries, but desirable citizens with their retinue of helpers. In many places where the dairy interests are important the windmill has rendered possible the production of butter. This is noticeably so in the western or butte region along the Wyoming line. Here in one instance, in a region of bare buttes and sand hills, is a ranch with no other improvements than a low sod house, a corral, and a windmill, with a rude milk house at its base. Here is *produced and sold annually* $900 worth of butter (without the

burden of taxes or rent) incidental to cattle raising, which is the primary occupation.

In this same region sheep raising is an important industry. A sheep herder's camp consists essentially of a windmill and a sod house, a tent, or a covered wagon. Around each mill are several thousand sheep. On these high lands wells are deep and the hand pump inadequate. It is apparent from inquiry that the windmill decides the fate of this extensive industry, and the author has been particularly interested to note its relation to the percentage of increase in the flocks. The rate of increase reaches and occasionally passes 100 per cent where ample water is provided, and falls below 80 per cent where the mill is out of order and neglected. In their distress for water the sheep neglect and even desert their lambs. A single case may seem unimportant, but viewed as a whole by one who has seen many square miles of such surroundings and conditions, the subject is exalted, at least in the mind of the writer, to one of great importance.

So far the windmill has been considered in its relation to the necessities of life, but its relation to some of the luxuries is not unimportant. The sight of a sod house with flower beds and a lawn sprinkler is unexpected and almost incongruous. Very different from the prevailing idea of frontier life are hot and cold water faucets. With the picture of cowboy life as the half-informed press paints it one would never expect to find in a ranch house marble basins and porcelain tubs. Such things exist, and are due wholly to the agency of the wind utilized by the windmill. The barest and bleakest spot is often the site chosen for the district school, but a windmill constructed by the pupils will change this barren scene—not common to the far West alone—in five years, and in nine years the sunburned spot may be so completely reforested that the district school itself will be concealed, and the entire place and its young occupants be shaded in summer and shielded in winter.

The author would not be misunderstood. The homemade mill is not the equal of the shopmade mill. But the homemade mill is an exceedingly important adjunct to the farm, and its cheapness is such that many men who can not afford a shopmade mill are able to construct one or more homemade mills. If necessary, there may be a mill in each field or at every well on the farm. The advantage of the homemade mill is its cheapness, and unless it can be put up at a small cost it defeats its object. In many extensive frontier regions freight rates seem necessarily so high as to preclude the use of shopmade mills. Native lumber is cheap, so that the homemade mill is entirely practicable. In Arizona there is promise that important tracts of waste but rich land may come under cultivation through the agency of the Nebraska windmill. The windmills supply the only element of fertility lacking—moisture.

In many countries, old and advanced in the arts, the use of the windmill is unknown; water is raised by hand, grain is ground by horse power, by water power, and by hand, and machinery is driven in much the same way, while the wind, with all its potential energy, is neglected. Our Eastern, Middle, and Southern States would also profit by the more general use of wind power. Those States, too, must learn that water, intelligently conserved and applied to the garden, truck patch, and small fruit at the right time, means superior crops with corresponding profits. The writer believes that the people of all States should come to realize that it is a much finer boast to claim advantageous facilities for irrigation than that there is no need of it.

There is often as much need of irrigation in Ohio, Indiana, and Illinois as in Nebraska. Wherever crops are drought-stricken from time to time irrigation is desirable. It is in these very humid regions that the windmill and reservoir would be especially efficacious, for a very little water run into the furrows at a critical moment would rescue the crop. In the Eastern States, where the thin, clayey soil is not fitted to withstand drought as are the soils of the Great Plains, a reservoir of water could flush a given patch with marked success. The writer anticipates the time when the lessons of irrigation in the West will be taught in the East, not only as a means of averting failure and loss by drought, but as a means of greatly increasing the quality and quantity of the yield. The windmill is one means to this end, not to be relied on solely, but to be available in any emergency.

On the Great Plains, where humidity decreases as rapidly as evaporation increases and where the available surface water is limited and the wind must be depended on, the windmill becomes a necessity. In traveling through Kansas and Nebraska 20 or 30 mills may be easily counted at one time from the car windows. At first the author believed that the windmill stimulus here was the product of necessity during recent years of drought, but he finds that more mills, both homemade and shopmade, have been going up during the present humid years than before. They are used as luxuries rather than necessities, and the present inference is that these winged specters are harbingers of prosperity.

At certain times and in certain places, however, they are still necessary, especially toward the less humid portions of the State, particularly in the broad river valleys, where wells are shallow and the supply of water inexhaustible. The rivers of Kansas, Nebraska, and the Dakotas are numerous, and some of them are important, but they are steadily being diverted from their channels into the irrigation ditches of States to the west. The total available surface supply is barely sufficient for the irrigation of 6,000 square miles out of nearly 77,000, one-half of which would be greatly benefited by irrigation. Recourse must be had, then, to such other means as superior cultivation, or

soil culture, for the catchment and retention of moisture; the impounding of water in ponds, lakes, draws, and canyons; tunneling into the sand hills and buttes; tapping the underflow of rivers; and raising water by means of current wheels, and by pumps driven by some motive power, preferably the wind. This outlook has given the windmill increasing notice of late.

COST.

The homemade windmill is supposedly built during unemployed hours by the owner or by his sons; so the cost of labor is not reckoned in these estimates. Old wire, bolts, nails, screws, and other odds and ends of hardware, old lumber, poles, and braces such as are common to every farm, enter largely into its construction. Even neglected mowers, reapers, and planters, old buggies, and wagons contribute material. Here are to be found good journals with oil cups, cranks, sprocket wheels, and chains, gear and bevel wheels of various combinations. The farmer who is inventive enough to build a mill is competent to see quickly the adaptability of certain parts to his ideas. It is this use of old and neglected material which is particularly recommended in this connection, for in making a mill of low efficiency, such as most homemade mills are, cheapness is the main object. Many mills have cost nothing whatever. Others cost $1, $2, and $3, and occasionally as much as $50, $75, and even $150. The average mill, such a mill as is needed for ordinary purposes, can be built for $2.50, which is an average from a large number, and its cost should not, and seldom does, reach $10. The writer considers $3 a liberal allowance for everything needed on the ordinary farm for the construction of a strong, satisfactory, and lasting mill large enough to pump for the house or stock. Such a mill, if rigidly made—inattention to this matter being the cause of more accidents among homemade mills than any other—ought to stand five or six years of uninterrupted service.

CLASSIFICATION.

However modified to suit the fancy and caprice of various builders the mills may be divided into four groups: Go-devil or jumbo mills of the overshot type; merry-go-round mills; turbine or opened-faced mills, including battle-ax, Holland, and mock-turbine mills; and reconstructed mills. These may be tabulated as follows, in inverse order of efficiency:

Classification of the principal types of homemade windmills in Nebraska.

(1) Jumbo mills (see page 35)	Baby jumbos.	
	Medium jumbos	With 4 fans.
		With 6 fans.
		With 8 fans.
	Giant jumbos.	
	Screw jumbos.	
(2) Merry-go-round mills (see page 44)	Unmounted.	
	Mounted.	

- (3) Battle-ax mills (see page 47) .....
  - With 2 fans.
  - With 4 fans.
  - With 6 fans.
  - With 8 fans.
  - Giant mills.
- (4) Holland mills (see page 54) .....
  - With 4 fans.
  - With 6 fans.
  - With 8 fans.
  - Giant turbines.
- (5) Mock turbines (see page 56) .....
  - Set turbines.
  - Revolving turbines.
    - Without rudders.
    - With rudders.
- (6) Reconstructed turbines (see page 64).
- (7) Shopmade turbines (see page 65).

DISTRIBUTION.

Nebraska seems to be the heart and center of the windmill movement. The famous Platte Valley, with its broad expanse and shallow wells, is a veritable windmill arena. From Omaha west through the State, a distance of 500 miles, and even beyond to Denver, there is a constant succession of these creations of a sturdy population.

During the summer of 1897 the writer engaged the services of three students, who were provided with teams, saddle horses, camp wagons, cameras, and camp accouterments in general, and drove from Lincoln to Denver, following roads south of the Platte going and north of the Platte returning. They found these unique and interesting mills everywhere. Going over the same ground in person the following year eight to ten mills were commonly found clustered about a town, each widely separated town having a dominant or prevailing type. Sometimes the mills were found on every farm and were too numerous to visit and report on. They are also found in the Republican Valley and the valleys of the Loup rivers and their tributaries. The State rises gradually from 900 feet in southeastern Nebraska to 5,300 feet in the butte region of the western boundary line, where the wind is often unreliable over considerable tracts, so that difficulty is experienced in running the most approved steel mills. The distribution of homemade mills is confined chiefly to river valleys and to certain sand-hill regions, where wells are shallow.

JUMBO WINDMILLS.

This is the lowest form of windmill. The jumbo, also known as the "paddle wheel" and the "go-devil," is simply an overshot wheel which bears the same relation to the air that the overshot wheel of hydraulics does to the water. It is a stationary mill, consisting of four or more paddles fastened to a horizontal axis set squarely across the direction of the prevailing wind, with the lower half boxed in. The smaller mills of this type are appropriately termed "baby jumbos." The larger jumbos are planted on the ground and baby jumbos on towers or buildings.

Being mills whose method of construction is obvious, they are favorites, particularly in the portion of the State lying east of Grand Island. West of that point the jumbo is usually replaced by the battle-ax mill, which the author considers a superior type. The jumbos are mills of low efficiency, but that matters not in the present discussion. They are efficient enough for all practical operations; that is the real question here, and theoretic considerations may be fittingly postponed. Those who have decided preferences for the jumbo need not fear disappointment. If the mills are well built they give satisfaction. If poorly made their efficiency may run as low as 15 or 20 per cent; but if built on the most approved plan they may register 40 per cent, as Professor Hood[1] has shown. In practice the poorest can pump a great deal of water, probably more than the ordinary family will use. In this connection it may be well, for the sake of comparison, to state that the efficiency of a good shopmade mill is at least twice as much as that of the jumbo, but the cost is ten to twenty times as much. For the capital invested the jumbo is probably more efficient than the best steel mill. The jumbo gives from one-eighth to one or two horsepowers, more or less, according to the wind, the size of mill, and other modifying conditions.

Professor Hood and his students in testing a 14-foot eight-fan jumbo found that in a good breeze it gave from one-tenth to one-fifth of a horsepower, and in a 38-mile wind it gave 1 horsepower. The power will vary according to the construction and position of the mill, and according to the wind and other factors. In Nebraska and Kansas the shafts of jumbos stand east and west, so that the fans may be struck by the prevailing wind, which blows from south to north, or at times in the opposite direction. The jumbo runs equally well whether the wind is from the north or south, but is motionless in an east or west wind. If from the intermediate points of the compass the fans are, of course, struck obliquely, but not altogether ineffectually. This virtually covers all winds, except rare and exceptional ones; hence daily working is assured, regardless of shifting winds. Nevertheless, some take the precaution to build jumbos with spiral or screw fans, in which event they do good service with winds from any quarter.

Jumbos are not wholly ornamental, but that is unimportant. The jumbo has served useful purposes on hundreds of frontier homes, and has many undeveloped possibilities awaiting the genius of succeeding generations of farmers. The average cost of such mills is about $[illegible]4, and they are sometimes used to singular advantage. Such mills, veritable toys, which cost nothing whatever, and were built in play by boys on the farm, have been put to work in earnest pumping water for the stock.

[1] New tests of certain pumps and water lifts used in irrigation, by O. P. Hood: Water-Supply and Irrigation Paper No. 14, U. S. Geol. Survey, 1898.

A BABY JUMBO WINDMILL ON GOODRICH FARM NEAR BETHANY NEBRASKA.

B. BABY JUMBO BUILT BY J. L. BROWN, KEARNEY, NEBRASKA.

NTED JUMBO WINDMILL ON GOODRICH FARM NEAR BETHANY NEBRASKA.

BABY JUMBO WINDWILLS.

The baby jumbo on the Goodrich farm, near Bethany (see Pl. V, *A*), is one of those referred to. It stands about 12 feet high, on the abandoned support of an old tank, and pumps water for the stock. Old parts from a discarded self-binder were ingeniously adapted to the existing needs. This small mill, with arms 2½ feet long, with four board fans each 4 feet long, and geared by sprocket wheel and chain in the ratio of 2 to 1, cost nothing, and pumps from an ordinary well water enough for the stock. This is an attractive and showy little mill, especially to those who are studying such matters, and is a credit to the boys who built it; it is introduced here, however, to show what can be done in this line rather than to encourage mills of this size or of this particular make. It is only a toy, but boys who can build one of this size are capable of building a larger one and of constructing it on approved lines if models are before them.

It is a safe assumption that, having at hand illustrations and descriptions of various windmills suited to home construction, many idle moments would be profitably employed in this work, both by men and boys on the farm and in the villages. Accordingly numerous examples, seemingly repetitions, will be reproduced in order that each prospective builder, without compromising his own individuality and personality, may have the right of accepting and rejecting plans, so as to embody in his own designs the desirable features of others.

The baby jumbo on the Goodrich farm was considered the smallest of its kind, but before a description of it could be penned a mill smaller by 1 foot, which, however, stands on a higher base, was found in the neighboring town of Havelock. This baby jumbo, built by Mr. W. W. Iler, has four fans 3 feet long, with arms 2½ feet long. It is attached by a 16-inch crank and rod directly to the handle of the pump. In a good wind (probably a 16-mile wind) this little mill, perched on a tower 16 feet high, discharged from a 60-foot well 400 gallons of water in forty minutes, or at the rate of 10 gallons per minute, as measured and reported by the owner. It supplies water for a boarding house and for the stock and cost only $3.70.

The remarkable little jumbo designed and built by Mr. J. L. Brown, proprietor of the Midway Nursery, 2 or 3 miles east of Kearney, Nebraska, is shown in Pl. V, *B*. It cost only $1.50, but pumped sufficient water to irrigate and save the garden truck, the strawberry patch, and the small fruit during the most trying season of drought recorded in the State. This is a surprising record for so small a mill, but it was carefully planned and well built. Differing from the ordinary proportions this mill is higher than broad. Its box is 3 feet wide, 9 feet long, and 6 feet high, with fans mounted on a gas-pipe axis. The axis and its crank, cost $1.50, while the rest was made out of the sides and ends of old coffee boxes, in accordance with the rule: Build

the jumbo cheaply or not at all. It is connected with the pump by a lever arranged in the ratio of 5 or 6 to 1. While means were not at hand to test this mill, in a good breeze it pumped water and was probably not overloaded by the weight of 200 pounds.

The practical benefits resulting from the mill are indisputable, and are well expressed by Mr. Brown, its builder, who says that the profits from the mill during the three years of drought and crop failure exceeded that from the rest of the farm. The claim is not that the profits are great, for such can not be expected from a small mill and about an acre of garden; but when this is all that is left it becomes relatively large. Let no one be deceived by this and grow too sanguine and overexpectant. The mill may not net its owner over $100, but if the rest of the crop is a total failure, this is worth more than one hundred cents per dollar. A case is known of a cucumber patch saved by a small stream from a windmill. This patch netted its owner $100 for pickles, cut and marketed during the month of September. The mill may easily exceed the profits of the rest of the farm during exceptionally poor seasons. The windmill is not the redemption of agriculture, but is an important aid at all times, and sometimes the only source of revenue.

This mill teaches a timely and suggestive lesson in economy in such work. Here by the exercise of a little foresight in securing an occasional packing box instead of lumber, an excellent mill was produced at a nominal cost, and could have been built without outlay by adapting an iron axle from some farm implement. This goes to show that baby jumbos, large enough to pump for the house, barnyard, and stock, are within reach of the poorest. The young farmer can often profit by picking up, almost at his own price, discarded wagon axles and old rods of iron, which are common at the village blacksmith's or at the city junk shop. A buggy or wagon axle, with the hubs or thimbles used for journals, will prove especially convenient to prospective builders.

JUMBO WINDMILLS OF INTERMEDIATE SIZE.

Baby jumbos are the least efficient of the homemade mills. Those of intermediate size, such as are commonly built by farmers and small market gardeners, will now be considered. These mills average about 8 by 12 feet; some cost nothing, others $6 to $8.

A good example is furnished by Dr. Boardman's jumbo mill on the edge of Overton. This mill was built to replace an old one put up three years before, and it was not necessary in this case to study strict economy either in the use of help or in the purchase of material. Good, new lumber was purchased, and a carpenter and smith engaged to do the work. When finished, this mill, with a box 6 by 12 feet, supporting four fans on an iron axis, each fan 5 by 6 feet, with a radius of 6 feet, was capable of supplying water for 100 head of stock; its cost was $8. The same mill could have been built by a man of

A. MEDIUM-SIZED JUMBO WINDMILL IN GARDEN OF M. J. OLSON, COZAD, NEBRASKA.

B. LARGE JUMBO WINDMILL AT CUSHMAN PARK GARDENS, LANCASTER COUNTY, NEBRASKA.

Size of mill 20 by 14 by 14 feet.

MBO WINDMILL (NO. 1) IN TRAVIS GARDENS NEAR LINCOLN, NEBRASKA, SHOWING PORTION OF RESERVOIR.

B SCREW JUMBO WINDMILL.

Photographs from models built by the author.

limited means for $2 or $3. Had it been a mill of six fans instead of four, it would have been a good model for others. It is a good mill, serves its purpose, satisfies its owner, and according to his estimate will pump water for 100 head of stock and continue in good order for five years or so to come. At that rate he is paying for his water service scarcely more than $1.50 a year.

The trouble with all four-fan mills is that but one or at most two fans are in the wind at any one time, while the six or eight fan mills may expose three or four times the surface to the impact of the wind. Accordingly, if other things are the same, the mill with more fans is apt to respond more readily to light winds.

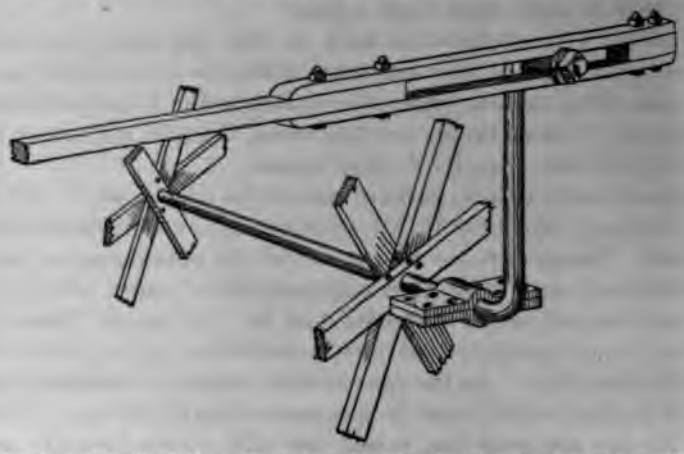
Comparable with this, in point of size, is the mill of Mr. W. W. Goodrich, at Bethany, shown in Pl. VI, which he believes was unnecessarily well made. Extra expense was incurred by purchasing a hardened Damascus steel axis, with good bearings and oil cups, which cost $5, and made the mill when complete cost $8. It has six fans, each 9 feet long, with a radius of 5½ feet, mounted on a box about 9 by 11 feet and 6 feet high. As the fans revolve there is a resisting cushion of air in the box, which must in a measure retard the fans. To overcome this the designer has raised the mill above ground, and has made the bottom movable in two parts or doors, which can be lowered to allow the escape of compressed air when the mill is revolving rapidly. When the wind is from the south the north door is opened, and vice versa. Mr. Goodrich says that a gas-pipe axle would serve his purpose as well as the more expensive steel one, and that with it he could build the same mill for $4. The baby jumbo on this farm, already described, pumps for the stock. The medium-sized mill irrigates a portion of a 6-acre tract set with egg plant for the Lincoln market. Mr. Goodrich has gone to considerable expense in attempts to raise water by horse power for the improvement of his farm, and especially for his extensive market gardens, and the present experiment is an attempt to use the wind as a much more economical means to that end.

At Cozad there is a jumbo of medium size, which is sensitive to light winds and is used in irrigating the market garden and small fruit of Mr. M. J. Olson (see Pl. VII, *A*). The box, which was about 9 by 13 by 6 feet high, carried six fans, having a radius of 6 feet and a length of 8 feet, mounted on a 1-inch iron axis with metal bearings and oil cups from old machinery. A 12-inch crank with friction roller was attached to the longer arm of a lever, 9 feet long (as shown in fig. 5), the shorter arm, 6 feet long, being attached to the pump rod. It pumps water with a 16-inch stroke from an 18-foot well with 3-inch casing without cylinder. It has pumped 1,200 gallons in an hour, as measured by its owner. The mill and all incidentals cost $20.

The jumbo may be constructed out of almost any waste or idle property. The axis may be of wood, gas pipe, or solid shafting, and the framework may be of poles cut from the place, the box of old lumber,

he sails of duck, burlap, sheeting, fencing, weatherboarding, store oxes, barrel staves, or old tin and sheet iron. All these adaptations re seen.

Two jumbo mills on the market garden of the Travis Bros., of Lincoln, afforded the writer an opportunity to see the workings of these



IG. 5.—Jumbo windmill of M. J. Olson, Cozad, Nebraska, showing 9-foot iron axis, 2 by 4 inch arms, journals, 2-foot crank, and walking beam.

ills and their practical results. Though hastily and poorly built, hey demonstrated their usefulness, and are easily worth their cost. One cost $8, the other $11. The two mills irrigate, as far as it is

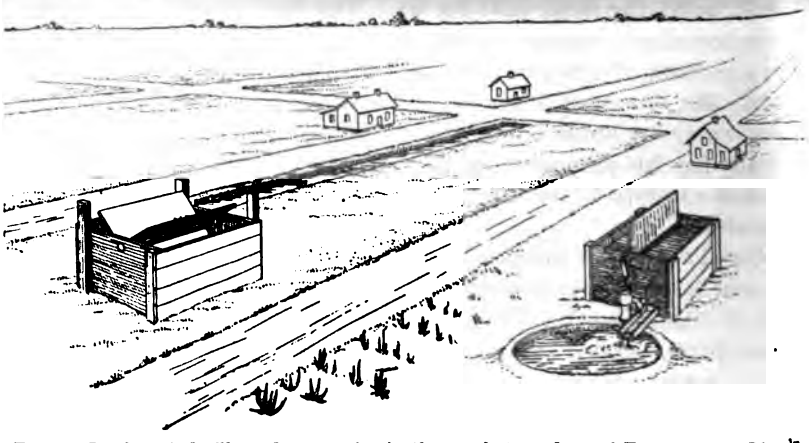
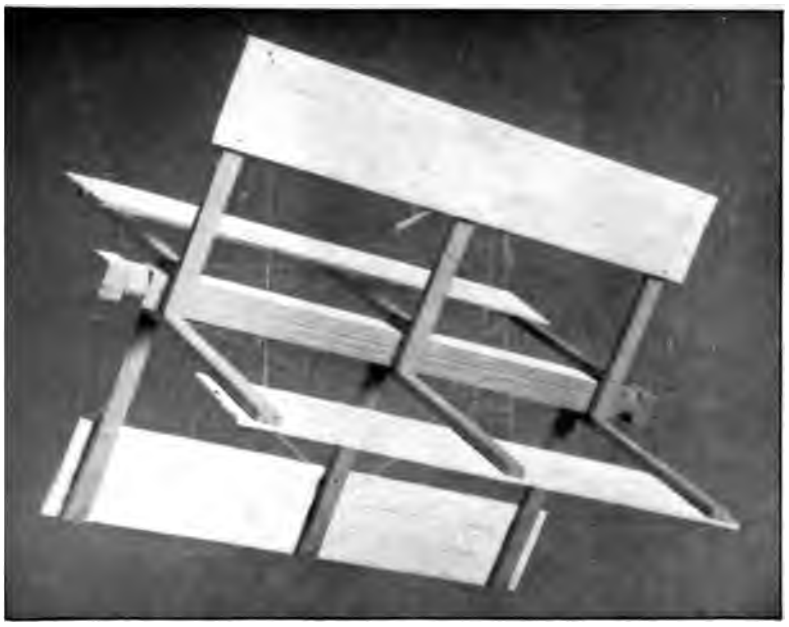


FIG. 6.—Jumbo windmills and reservoirs in the market gardens of Travis Bros., Lincoln, Nebraska.

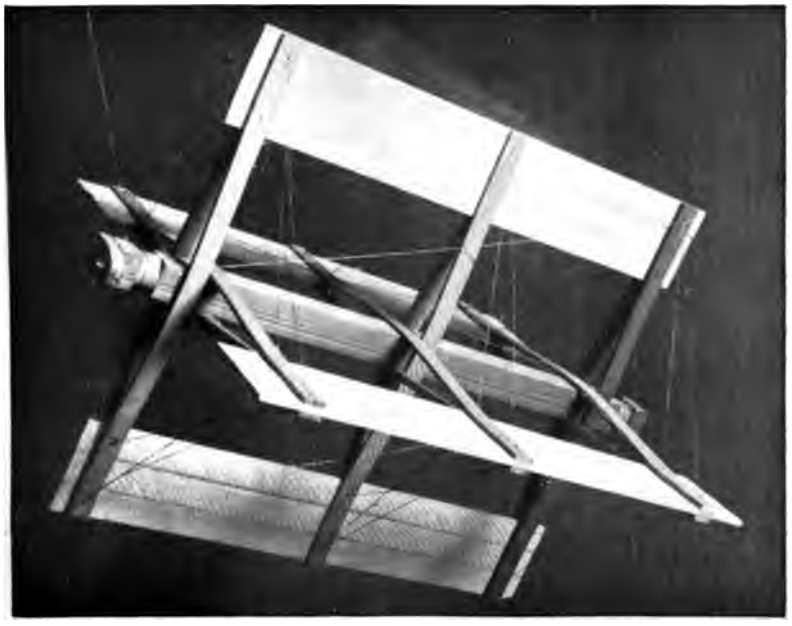
desirable to irrigate in this region, about 8 acres of garden. According to the gardeners the yield was ahead of the demand of the market.

Mill No. 1 (shown on the left in fig. 6), with a box 9 feet wide, 13 feet long, and 8 feet high, carries four fans of burlap, each 9 by 4 feet, stretched on arms 6½ feet from the center, and pumps water into a long,



A. METHOD OF ATTACHING ARMS OF JUMBO WINDMILLS TO AXIS.

Photographed from model built by the author.

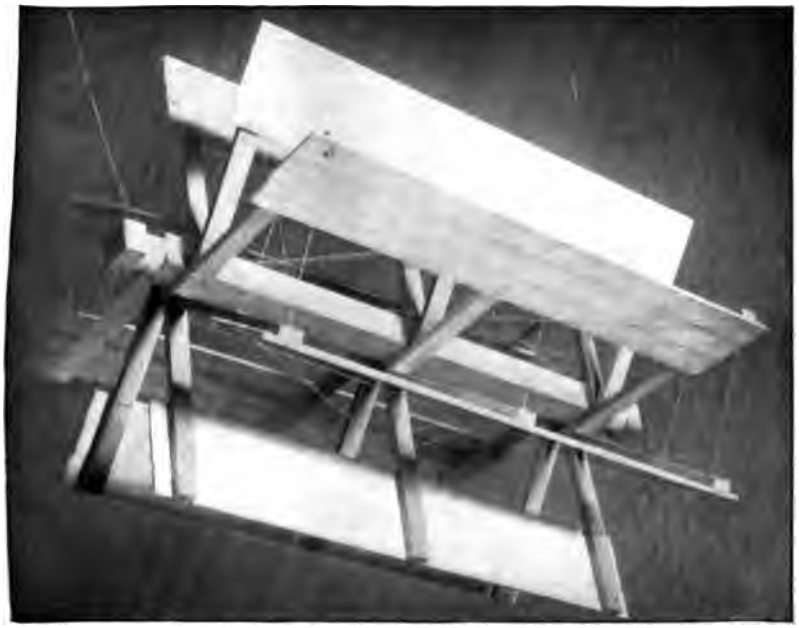


B. ANOTHER METHOD OF ATTACHING ARMS OF JUMBO WINDMILL TO AXIS.

Photographed from model built by the author.

A METHOD OF CONSTRUCTION OF SIX-FAN JUMBO WINDMILL CROSS-BRACED BY TWISTED WIRE

Photographed from model built by the author.



B METHOD OF CONSTRUCTION OF EIGHT-FAN JUMBO WINDMILL CROSS-BRACED BY TWISTED WIRE

Size: 12 to 14 feet long, 10 to 12 feet in diameter. Photographed from model built by the author.

narrow reservoir, 150 by 4 by 2 feet deep, skirting the higher edge of a 5-acre patch. The grade was such that the rows of vegetables were quickly flushed with water when necessary. At the four corners of the box are four uprights or standards, carrying on top a pulley with rope attached to a sliding cut-off or wind guard, to be raised and lowered in adjusting the mill to winds of varying velocity. These guards, constructed on a wrong plan, greatly increased the expense for lumber. Mill No. 2 (shown on the right in fig. 6), of about the same size, cost $11, and irrigates an adjoining 3-acre tract successfully, but is capable of doing more work.

In the case of these two mills a defense is found for the adoption of the cheap homemade mill. The position of these two gardens in the outskirts of Lincoln made two mills necessary. The enterprise was in the nature of an experiment; accordingly from a business standpoint it was assuming much less risk to erect two cheap mills than to put up two steel mills, each of which would probably have cost twice as much as the two jumbos together. If successful when well established and past the experimental stage, the enterprise may deserve a better type of mill, whether homemade or shopmade. (See VIII, *A*.)

The argument for the jumbo on the ground of experiment is further exemplified in the case of the John Tannehill nursery and garden at Columbus. Finding that his orchard thrived and that it was well set with fruit, which, however, fell off before reaching maturity, he inferred that this was due to insufficient moisture, and proceeded to experiment by building a large jumbo, which has become a sort of landmark. It is a large mill, capable of driving two 6-inch cylinders and of irrigating about 10 acres of orchard. It is built on approved plans, especially with respect to the fans. The six 16-foot fans have long arms (9 feet), not boarded up solidly, but with a space below for the "dead air"—that is, the air which has struck the fan and used up its energy. The object is to get rid of this as quickly as possible, thus making room for fresh air with unexpended energy. There are six fans, well bolted, wired, and braced, mounted high on a box, substantially made and securely anchored. The mill pumps water into a reservoir, from which it is drawn off to irrigate the orchard.

This experiment, which cost $100, was a success. By artificially supplying a little more moisture the orchard holds and ripens the fruit which formerly dropped off prematurely.

SCREW JUMBO WINDMILLS.

The screw jumbo (see Pl. VIII, *B*) is of rare occurrence, the author having found but two in the State—one at Trenton, Hitchcock County, and the other at Ainsworth, Brown County. While it is altogether probable that they are not so efficient as their enthusiastic builders believe, they are successful and are not lacking in interest to the student of windmills.

Perhaps one claim to superiority is well grounded. The screw jumbo—also known in the vernacular of the Great Plains as a "regular stem-winder"—receives wind from the east and west almost as well as from the north and south. Their builders say that they respond to wind from every quarter. The sails, which are of duck, although thin wood might be used, are not stretched on a line parallel with the axle, but pass diagonally from one arm to that next behind it, and so on, producing a twisted or auger-shaped effect in the mill. The claim that the mills run with great steadiness is doubtless true, for it is readily seen by a glance at the cut that each fan receives the advantageous wind progressively throughout its entire length, and that the fans are not alternating between advantageous and disadvantageous positions in the wind. A glance will be sufficient to show that some position of the fans will be struck, no matter in what direction the wind may blow. The boxes for screw jumbos are boarded up on the sides, but left entirely open at the ends.

CONSTRUCTION OF JUMBO WINDMILLS.

The jumbo, as before stated, is a mill of low efficiency at the best, a fault made more pronounced by careless construction, lack of rigidity, and poor anchorage. The mill, as well as the farm sheds and outbuildings, should be strong enough to weather the blast and storm. Lack of rigidity is another fatal oversight. The round wire nail when first driven home seems strong, but constant vibration may draw it slightly, or the hole may be enlarged so as to allow too much play, foreshadowing ultimate destruction. This may be avoided by the use of an occasional bolt. Bolts are cheap and may be obtained at any hardware store. The fans should be bound together by fencing wire, rendered taut by doubling and twisting. Good anchorage is readily obtained by burying posts with crosspieces on the bottom and stamping the earth firmly around them. These measures of precaution should always be observed, especially in the case of large mills. The probability of failure and disappointment should be forestalled by rejecting the popular four-fan mill and accepting the six *or eight* fan design instead. One of the worst errors of construction

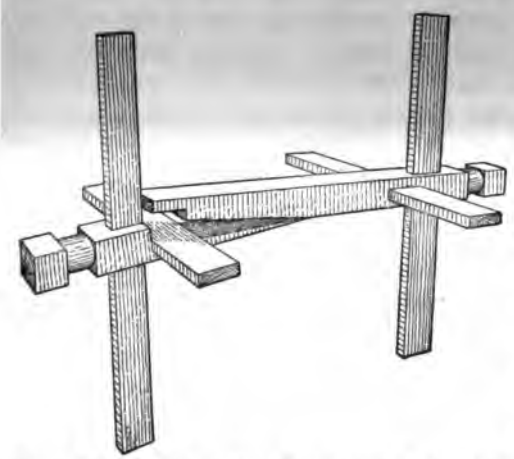
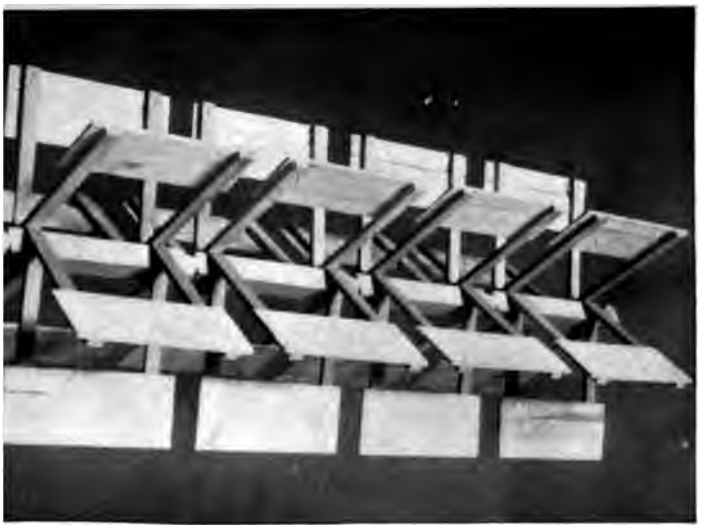


FIG. 7.—Break resulting from improper method of fastening jumbo windmill arms on the axis.



I. METHOD OF CONSTRUCTION OF GANGS OF JUMBO WINDMILLS.

Photographed from model built by the author

THOD OF CONSTRUCTION OF SCREW JUMBO WINDMILLS WITH CANVAS SAILS AND ARMS BRACED WITH TWISTED WIRE

Photographed from model built by the author

A. GANG OF JUMBO WINDMILLS ERECTED ABOVE CORNCRIBS OR SHEDS.

Photographed from model built by the author

B. JUMBO WINDMILL WITH WIND GUARD OR CUT-OFF.

Photographed from model built by the author.

is to weaken a part which is subject to stress and strain. An example of this is found in the way holes are mortised through axes for the arms, as shown in fig. 7. When an 8 by 8 inch axis, having a span of 18 feet, is cut through at each end to admit 2 by 4 inch arms, it is disqualified for long use.

Methods of attaching the arms are shown in fig. 7 and Pls. IX, X, XI, which are self-explanatory. When loaded down with heavy arms and fans it is a severe test for any stick of timber or gas pipe or shafting to span 15 or 18 feet. Accordingly the author proposes what he may call twin, triplet, and quadruplet or multiple jumbos. By this means a jumbo of any length and of almost any strength is possible, for the axis has support every 8 or 10 feet. (See Pls. XI, *A*, and XII, *A*.) This, the writer believes, is the means of making powerful jumbos, especially if a chain and bucket are used instead of a pump. In regions of shallow wells these gangs of jumbos might be used for irrigation on a larger scale than is possible with the ordinary jumbo.

It seems so essential that the jumbo should be cheap that the author would minimize expense by doing away with the box and by adapting sheds and buildings to this use. Every well-regulated farm has its complement of sheds. It will cost no more to arrange them with reference to carrying the fans of a jumbo or multiple jumbo. Corncribs which are built in pairs facing each other with a driveway between seem suited to this purpose, as shown in Pl. XII, *A*. In the mill illustrated the fans are slowed down by a brake and are then tied, as is the common practice. In this case the cut-offs or wind guards are omitted, it being assumed that the mill is well enough built to resist storms and wind. Rafters could be extended to support the axis. The labor and expense in that case would be confined to the construction of the driving parts or fans. Many mills could be built without cost. By the multiple plan mills might be built of sufficient strength for shelling and grinding as well as for pumping.

Many men increase the cost of their mills by wind-breaks, guards, or cut-offs in use. Some allow their mills to run in whatever wind blows, others adjust breaks in such a way as to regulate them, others build sliding guards, which run up and cut off the wind wholly or in part, as need be. The author would suggest that it is as easy and less expensive to let the sides of the box itself be adjustable, as shown in Pl. XII, *B*, instead of building cut-offs, one on the north side and the other on the south side of the box. If balanced, the sides could be raised and lowered with little exertion. Or, simpler still, the north and south sides of the box might be hinged so as to be let down; then the wind, striking equally against the top and bottom fans, would stop them. If objected to on the ground that the fans thus unprotected are exposed to too much wind, it may be rejoined that there is no reason why they should not be made strong enough to resist it as

easily as the cut-off. One could check the mill or stop it outright, according as he lowered the door a little or dropped it flat.

The arms should be of good length, say 5 to 7 feet, thus securing leverage with light fans, which seems better than to use a fan of less radius and greater length and weight. The fans should cover about one-third of the length of the arms. If the axis is of wood it must be rounded at the bearings, care being taken that as little as possible be cut away, otherwise the axis will be weakened. The crank is easily made, and if the size of the mill warrants it there should be one at each end. Some prefer wood, others metal; it is a matter of indifference which is used, so that it is rigid.

PUMPS.

Mechanically the best pump is faulty. Other things being equal, the endless chain of buckets is doubtless better. Here the pressure is not intermittent, but is constant at all times. These buckets are adapted to sprocket wheel and chain, and where the lift is not too great these are to be recommended. The pump, however, is the familiar water lifter and the one generally adhered to. When the mill is large enough to warrant it, two pumps of sizes suited to the mill should be used, but it should be remembered that it is probably as great waste of energy to overload as to underload the mill.

MERRY-GO-ROUND WINDMILLS.

Windmills of all makes have natural limitations, and the merry-go-round is a realization of an attempt to devise mills of unlimited size and strength. The larger ones are of rare occurrence, but are seen in several parts of the State. The smaller ones are mounted on towers, the larger ones on the ground, as shown in Pl. XIII. The former are the more common and look like elevated water tanks, for which they are often mistaken.

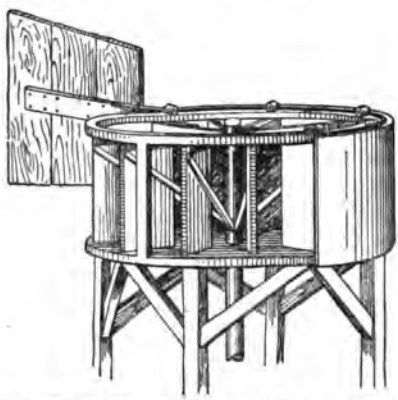


FIG. 8.—Hooded merry-go-round built by William Winn, Berwin, Nebraska, showing semicircular hood on rollers guided by large rudder.

The fans revolve about a vertical axis, and surrounding all is a series of movable shutters, which come together and form a sort of closed cylinder when the mill is out of gear. When in action they are partly opened, admitting air to the fan on one side and excluding it from the other. But these are quite as limited in size as other mills, and so defeat one important purpose of the merry-go-round. This kind, which is

SMALL MOUNTED MERRY-GO-ROUND WINDMILL NEAR LINCOLN, NEBRASKA

taken as the lowest of its order, is generally small, perhaps 6 to 12 feet in diameter and 6 to 12 feet high, exclusive of the tower. It is of doubtful efficiency, though in active operation, and is intricate enough to require skilled labor and expensive material, which in part unfits it for general adoption. One seen at Grand Island, on the farm of Mr. Henry Joehnck, when built fourteen years ago, rendered important service in irrigating garden truck for the Grand Island market. At Greeley Center a similar mill, 20 feet in diameter, is used for grinding, there being a lack of water power.

The merry-go-round mill of Mr. William A. Winn, of Custer County, consists simply of a series of fans radiating from the central axis. Around the same axis revolves a great semicylindrical hood or cut-off, shown in fig. 8, running on friction rollers and guided automatically by a large vane. When in action half of the fans are exposed and half protected, as shown in plan (fig. 9). The mill is thrown out of the wind by swinging the shield fully around in the direction from which the wind comes, thus covering all the fans.

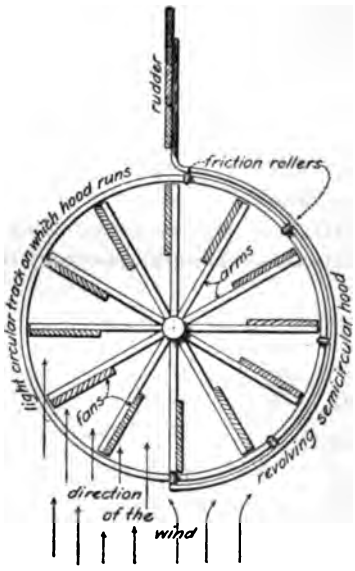


FIG. 9.—Plan of hooded merry-go-round windmill built by William Winn.

These are mills capable of many modifications and adaptations. They are easily built, braced, and supported, and no mill perhaps lends itself more kindly to unlimited extension, all of which should bring them into prominence that they have not yet enjoyed; important results may be expected from these mills. This type of mill is worthy of development.

In western Nebraska, near the Colorado line, where the precipitation runs as low as 12 to 15 inches and evaporation as high as 6 feet, irrigation begins to be imperative. Here 10 acres have been successfully irrigated by Mr. E. E. Blackman's merry-go-round, and this is more of a test than it would have been in a more humid portion of the State. This mill, as he describes it, is 24 feet in diameter and carries numerous swinging door-like fans of light wood 6 feet high by 4 feet wide. The fans are free at one edge, as shown in plan in fig. 10, and, like a flag floating from the mast, they swing edgewise against the wind, this being the line of least resistance. But the moment the center is passed each fan in turn swings back against the immovable arms and exposes its 24 square feet of surface to the impact of the wind. Half of the fans are continually in the wind and half out of it. Such a mill, well made, might be an

engine of strength, but careful work and well-considered plans are necessary to avoid resistance and loss of power. Mr. Blackman insists that this is the cheapest and most efficient mill for its weight that can be built. His mill cost $4.75, exclusive of home labor, pumps an 8-inch stream, and irrigates 10 acres.

A similar, though larger and much more elaborate mill, designed and built by Mr. S. S. Videtto, may be seen on a ridge near Lincoln. (See Pl. XIV, *A*.) The mill is probably 40 feet in diameter and 12 to 14 feet high. It runs on a circular steel-rail track, and is connected by cogwheels to a tumbling shaft which drives the pumping machinery.

These mills are broad of base, and correspondingly stable. There is no apparent limit to their size, and they may embody important ideas.

It is certainly desirable to have some powerful windmills, and the author has designed several which, though too large, perhaps, to be practicable, were conceived in the hope that some available means of raising the underflow waters of the Platte and other rivers might yet be found. Here, at a depth of 4 or 5 feet in coarse pebbles, is an inexhaustible supply of water, of which but meager use is made. The advent of a good water lifter will revolutionize all this. At present but an occasional seepage or underflow ditch is dug, such as the Gould-Hollingsworth ditch at Ogallala. The trouble lies not in the supply, but in the fact that one must go upstream 4 or 5 miles to get the required fall. For private ownership the expense is often prohibitive. It requires no engineering feat to devise and construct windmills powerful enough to do this work, and the author confidently hopes for its realization.

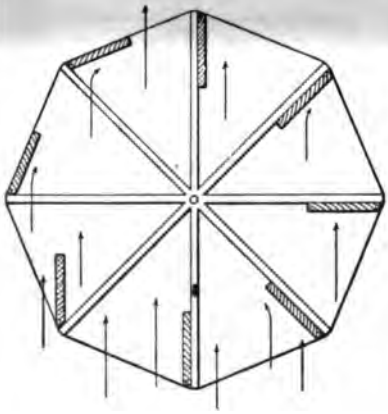
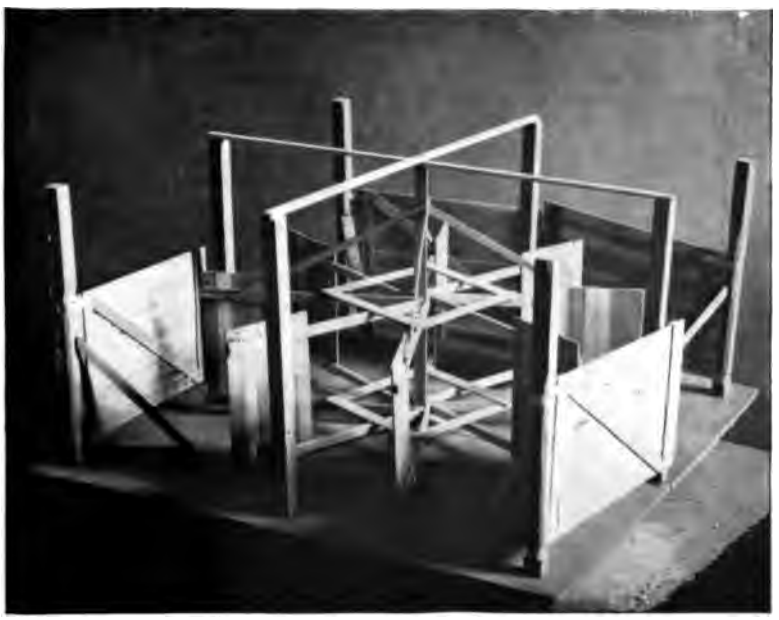


FIG. 10.—Plan of large merry-go-round windmill of E. E. Blackman.

The merry-go-round, when perfected, gives great promise. In the construction of these mills the importance of rigidity is again to be emphasized, for especially light material enters into their make-up. Bolts and twisted wire should be used freely. Where cogwheels and shafting are not at hand, they can be obtained in the market. The axis may be a suitable pole cut from the place and guyed securely by wires in several directions, and the mills may be so set between sheds as to shield part of the fans; or swinging doors, as shown in Pl. XIV, *B*, may be used to possible advantage. They may also be mounted on sheds. The arms ought to be made of new lumber, but packing

A. MERRY-GO-ROUND WINDMILL BUILT BY S. S. VIDETTO, LINCOLN NEBRASKA.



B. SUGGESTED FORM FOR EIGHT-FAN MERRY-GO-ROUND WINDMILL.

Photographed from model built by the author.

boxes would furnish material good enough for the fans, which may be made of wood, duck, or sheet metal. Pl. XIV, *B*, illustrates an eight-fan merry-go-round windmill designed by the writer. The diameter is 20 to 25 feet, and the fans 6 to 9 feet. Four gates or wind guards, each of which is so hung upon the corner post as to swing through 270°, easily throws the mill in or out of action. The high-geared wheels and shafting below are not shown.

OPEN-FACED OR TURBINE WINDMILLS.

Open-faced or turbine mills may, for convenience, be divided into five distinct kinds, as follows, arranged in inverse order of their importance: Battle-ax windmills, Holland windmills, mock turbines, reconstructed turbines, and shopmade turbines.

These are the windmills of preeminent importance. They represent the most specialized type of windmill, and the man who is about to construct a mill of some other form, though in great favor locally, may well afford to consider the possibilities which this kind of mill affords. The simpler mills are easily constructed, and are inexpensive, efficient, and altogether superior, in the estimation of the writer.

BATTLE-AX WINDMILLS.

In its simpler form this mill consists of a tower for the support of a horizontal axis and crank, to which arms are attached bearing at their extremities fan-like blades, which have a real or fancied resemblance to a battle-ax; hence the name.

Justification for this is found in the fact that the arms—which are the handles—each carry a fan, shaped in some instances like a battle-ax. It is certain that their keen edges cleave the air in a belligerent fashion. When viewed from the side an optical illusion is produced, and these revolving blades seem to be slashing wildly at space in opposite directions. However, they fight their way through, and are victorious mills, worthy of praise.

Like the jumbo and set turbines, the battle-ax mill has its axis set in the direction of the prevailing wind—that is, north and south. The axis may be of wood, rounded to fit in wooden bearings, or it may be of wood, but with metal ends or bearings, or it may be gas-pipe shafting, or, as is not uncommon, the axis of a buggy or wagon. This is the fundamental part, and to it are attached the four fans, six fans, eight fans, or many fans, as the case may be. The jumbo itself can not exceed the battle-ax in simplicity, cheapness, or power. The battle-ax mill is presumably the superior of the jumbo in all respects. These are mills of simple, cheap, and easy construction, and are efficient. In size they run from 8 to 10 feet, the more common sizes, up to powerful mills 16 feet in diameter.

Grand Island, in the Platte Valley, about 90 miles west of Lincoln, is a center for windmills. They are found in the town and for miles

around. Irrigation in this portion of the State is not strictl
sary. It is simply a way of increasing the ordinary quantity o
of the yield, and is resorted to sparingly. Some of these mill
nearly indistinguishable from the shopmade mills that they
be reproduced. The majority are of the battle-ax type,
especially commended to the attention of farmers and stockn

The four-blade battle-ax, about 8 feet in diameter, is the
type around Grand Island and farther west. Such a mill, wit
ing capacity sufficient for 100 to 125 head of cattle, may cost
but should not cost $10, and may be built by those who are i
without any outlay. Poles and strong limbs answer the pu

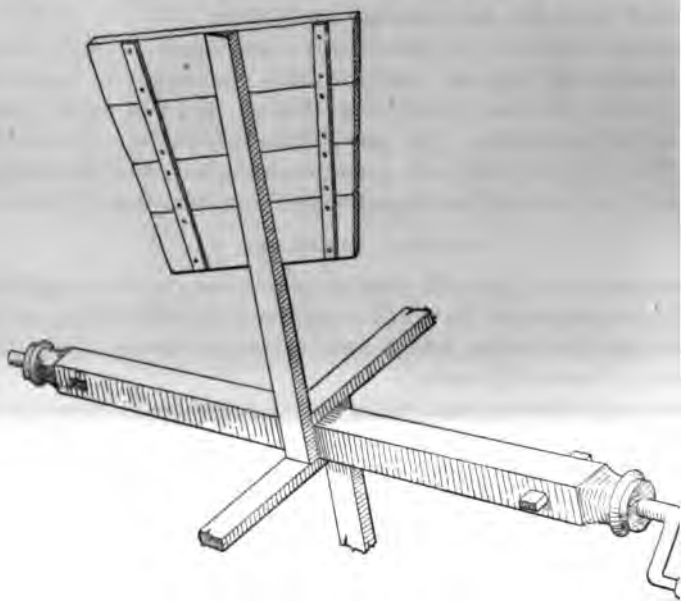


FIG. 11.—Details of construction of battle-ax windmills, showing axis 8 feet long, 6
square, iron bearings, arms 6 feet long, fans about 3 feet square, made of thin l

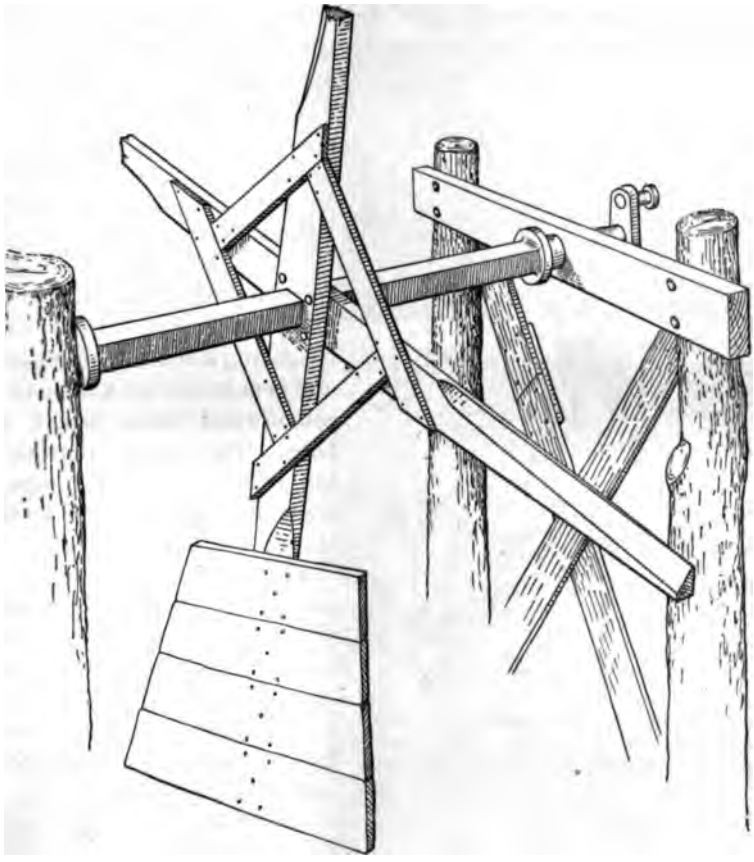
well as new lumber, old dry-goods boxes furnish material
for fans, and old wire, nails, and bolts are common on eve
The majority of the mills are made in this way, although
much more elaborate. The principle of the adaptation of d
machinery is particularly exemplified in the constructio
battle-ax mills. In most of them the journals, gearings, rods,
wheels, nuts, bolts, braces, and lumber of discarded machi
used. Accordingly they are provided with well-made and fa
tionless bearings, which help to render them sensitive to ligh

The mill of Mr. Jacob Geiss, near Grand Island, which
regarded as typical, is a 12-foot four-fan battle-ax, with a
feet long, mounted upon a suitable tower. It pumps from a
well more than is required for 125 head of cattle. (See fig. 1

A. BATTLE-AX WINDMILL ON FARM OF MATTHEW WILSON, NEAR OVERTON, NEBRASKA.

B. BATTLE-AX WINDMILL ON FARM OF FRED WOULF, NEAR GRAND ISLAND, NEBRASKA.

From Grand Island westward to Ogallala the battle-ax is the dom-
nt type of homemade mill. At Overton, on the farm of Mr.
tthew Wilson (Pl. XV, *A*), are found two battle-ax windmills, each
a quarter section of a beautiful and improved farm of 1,600 acres,
each pumping water for 50 head of cattle. This is a large farm,
with several hundred head of cattle, as many hogs, and a barn full
ilch cows and horses, it was found convenient to supplement the
of two large Perkins mills with two battle-ax mills. The two



—Working parts of a four-fan battle-ax windmill on the farm of Matthew Wilson, Overton, Nebraska.

were built at a cost of $1.50 each, and each pumps for its quar-
ction. In addition, one pump irrigates successfully 1 acre of
n, the water being conducted from the pump to the rows by
galvanized-iron pipe. Nowhere is there a more intelligent use
terial. Three cottonwood poles, as shown in fig. 12, properly
red and braced, constitute the tripodal tower, a buggy axle and
les the axis, and thin lumber the fans. In these bearings—kept

well oiled—the mill runs as smoothly as formerly did the c wheel on its spindle. The crank is adjustable to an 8-inch o stroke, as desired. (See Pl. XV, *A*.) In Pl. XV, *B*, is sho battle-ax wind-mill, tower, milk-house, and stock troughs c Woulf, near Grand Island, Nebraska. The diameter of the 10 feet, and the cost $3 to $5. This mill pumps water for 48 cattle. The method of construction is shown in fig. 13. To mill the rope attached to the long crank is made fast to a clea base of the tower.

Six- and eight-fan battle-axes differ from four-fan mills ch numbers. However, they are usually considerably larger and va modified, and worthy of mention, at least in sev stances.

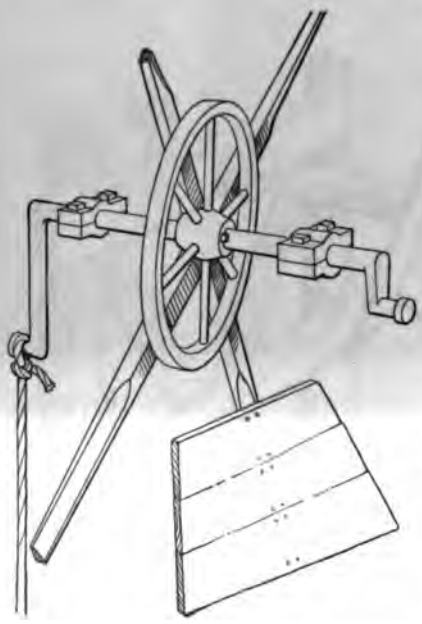


FIG. 13.—Method of construction of the battle-ax windmill of Fred Woulf, near Grand Island, Nebraska. Brake rope and crank to the left.

The six-fan battle-ax w of John Harders, near Island, Nebraska (see P *A*), is 8 feet in diamet cost, including tower, pu pipe, $12 to $14. It is u irrigating a small market and is mounted on a firm cottonwood poles, broad base. The brake, mana the brake rope, rubs ag cogwheel keyed to the a thus controls the wheel.

The eight-fan battle-a mill of Mr. Diedtrich Hu (Pl. XVI, *B*), near Grand attracts special attenti cause it is made of old m at a cost of but $14, in the mill and an unusual and well-ironed water tan mill alone cost $6 to $8, and in efficiency is a rival of the st costing ten or twelve times as much. The diameter of the 10 feet, and the stroke 8 inches. The mill was located in tl yards, bordered by stalls and pens, and pumped from a well all of the water needed by the stock. It was suppo heavy cottonwood posts, on which was bolted the framework thrashing machine, with journals and cogs in place. The co geared in the ratio of 3 to 1. The fans, which are 3 feet inches wide below and 20 inches wide above, were made of tl and ends of boxes. Advantage was taken of the fact that pulley was attached to the shaft (fig. 14). A friction brake, m

A. SIX-FAN BATTLE-AX WINDMILL OF JOHN HARDERS, NEAR GRAND ISLAND, NEBRASKA.

B. EIGHT-FAN BATTLE-AX WINDMILL OF DIEDTRICH HUENNECKE, NEAR GRAND ISLAND, NEBRASKA.

by an old wagon brake, was cramped on the pulley, checking or stopping the mill.

The largest and most remarkable battle-ax mills in the State are probably those of J. S. Peckham, 5 miles southwest of Gothenburg, and of his son, E. L. Peckham, a mile distant.

These are veritable wind engines, and they probably illustrate what may be done by the homemade mill better than any of the other mills visited. On this splendid farm, of a thousand or more acres, there is an interesting array of windmills, houses, barns, grain houses, sheds, cattle yards, orchards, vineyards, and the young but lofty trees of a timber claim. There were four shopmade mills, one Dempster, two Perkins, and one Aermotor, pumping water for the stock and for the

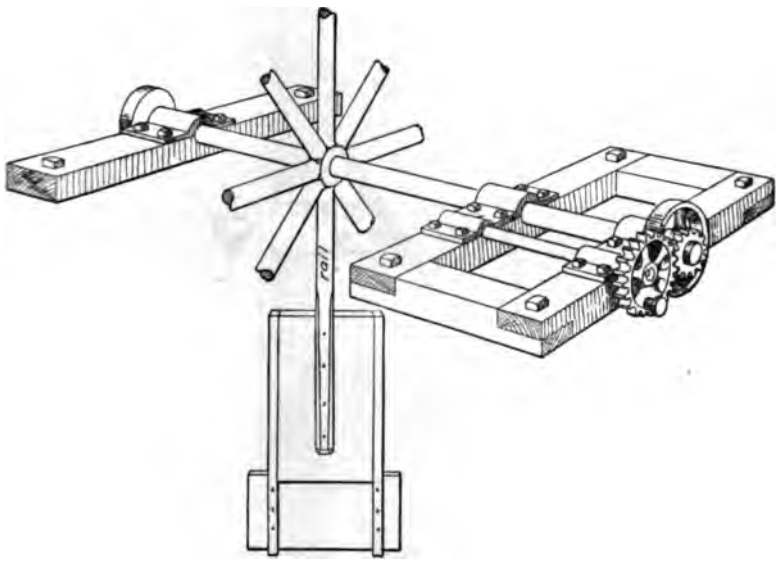


FIG. 14.—Working parts of the eight-fan battle-ax windmill of Diedtrich Huennecke, near Grand Island, Nebraska, with one fan in position.

house, and two giant battle-ax mills, driving two pumps each for the irrigation of 15 acres of orchard, vineyard, and small fruit.

These mills were designated Mill No. 1 and Mill No. 2, shown on the left and right, respectively, of Pl. XVII, *A*. Both were mounted on the same kind of tower, and were identical in size and make. No. 1, however, worked two pumps with 3¼-inch cylinders, and No. 2, two pumps with 4-inch cylinders, so that the results, as shown by the amount of water discharged, were quite different.

The towers, each about 20 feet in height, were made of timbers 2 by 4 inches with pieces 4 by 4 inches for the corners. They were broad at the base, about 16 feet square, and well cross-braced. The wheel,

16 feet in diameter, consisted of eight heavy wooden fans 5½ feet long and 5 feet at the top, tapering to 2½ feet below (about 25 square feet of surface on each fan). These were cross-cleated and very rigidly made and then securely bolted on a slant to the double 2 by 4 inch arms. The arms were made by springing and bolting into position pairs of 16 feet 2 by 4 inch timbers over the axis, which was 8 inches square and had a span of 16 feet. The axis was not solid, but consisted of

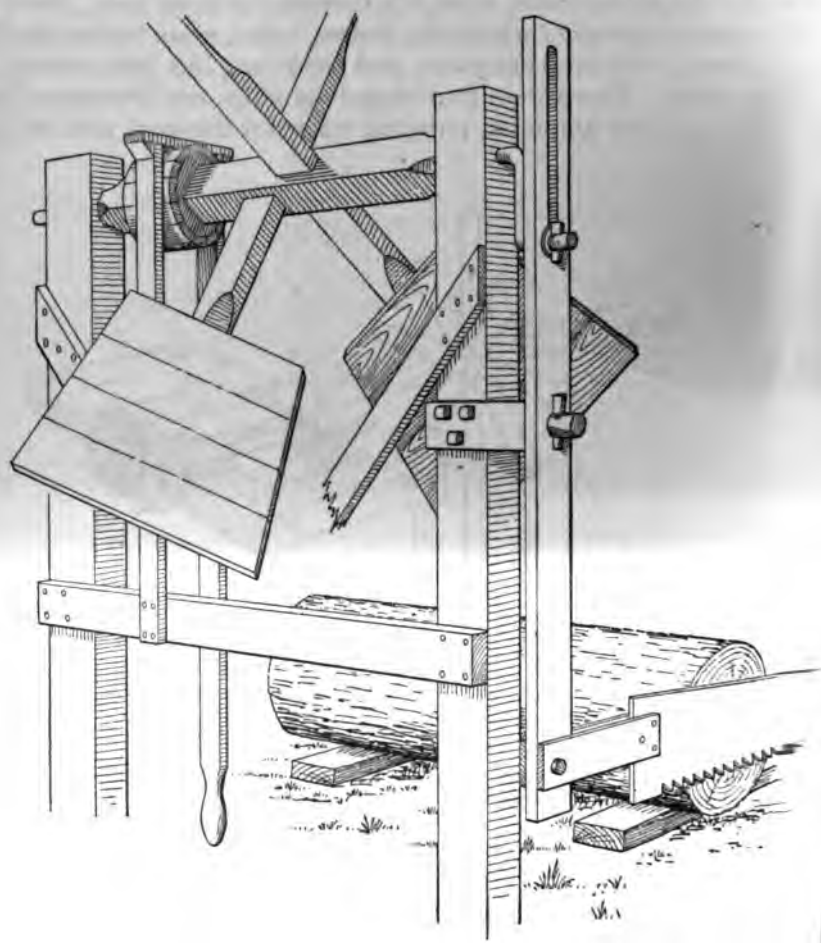


FIG. 15.—Battle-ax windmill driving crosscut saw, built by A. G. Tingley, Verdon, Nebraska.

two planks 4 by 8 by 16 feet, spiked and bolted together. This offered an advantage in the judgment of the designer, in that it allowed the adjustment and keying in place of the 2-inch iron bearings which carried the cranks and on which the axis was to turn. Their size demanded special rigidity, which the designer did not overlook at any point. They were admirably constructed, and ran as smoothly and as noiselessly as a steel mill. They cost about $25 each (exclusive

A. GIANT BATTLE-AX WINDMILLS ON FARM OF J. S. PECKHAM, NEAR GOTHENBURG, NEBRASKA.

B. TWO-FAN BATTLE-AX WINDMILL BUILT BY ELMER JASPERSON, ASHLAND, NEBRASKA.

labor) and partly irrigated 15 acres of orchard, which they are able of irrigating well when the water is economically and prop- applied.

s to efficiency, Mill No. 1, with two 3-inch cylinders and a 10-inch ke, pumped in a 13.5-mile wind at the measured rate of 14,760 gal- in twenty-four hours from a well 42 feet deep, although one valve badly out of order.

ill No. 2 made a better record, both because of the larger cylin- and the better condition of the valves. In a 13.5-mile wind this , with a 10-inch stroke, discharged at the rate of nearly 1,000 gal- per hour (or to be exact 930 gallons per hour), or 22,320 gallons wenty-four hours, from a well 42 feet deep. This amount was ıtly exceeded when, later in the day, the wind velocity rose to 15 s per hour. Though not apparently overloaded, Mill No. 2 ran reciably slower than No. 1.

rom the farmer's standpoint, mills capable of doing such work can be purchased at a price commensurate with the cost of building n. Thus some have built mills who otherwise would have bought n. These two mills are a credit to any estate, and are commended he author to the consideration of farmers who prefer to build their dmills for heavy service.

. mile distant is the farm of the son, E. L. Peckham, who owns perty almost as extensive as that of the father. The farmhouse s like a city residence, with its fine green lawn. The young ıard, large vegetable garden, and flower garden, 2 acres in all, are lels, due to the water supplied by a mill exactly similar in all ects to the original battle-ax mills Nos. 1 and 2, except that this is e heavily braced and otherwise improved. It lifts water 27 feet by pumps with 4-inch cylinders, irrigates 2 acres, and sprinkles the n. The total cost, including pumps and all incidentals, was $75.

he remarkable two-fan battle-ax mill of Elmer Jasperson may be ı near Ashland, Nebraska, mounted along the ridge pole of a north- h corncrib and wagon house (see Pl. XVII, *B*). Heavy semicir- ır fans of wood, with a diameter of 10 feet, are mounted on a sub- ıtial axis having a span of 12 feet; to this is attached the sprocket el and chain for transmitting the energy of the wind to the corn ler and feed grinder below. These fans are movable, and when ıght together form a circle 10 feet in diameter, with its edge to wind, in which position the fans are not affected by the wind, and ccordingly out of gear; but when thrown aslant the wind strikes r oblique faces, and they revolve with a fine display of force.

his mill is not so sensitive to light winds as shopmade mills, but nomentum is greater. It drives a two-hole cornsheller and feed ıder and a grindstone.

his is one of the most interesting and attractive homemade designs he State, and for novelty and originality it was awarded a prize by

the Nebraska State Journal of Lincoln. It shells and grinds corn at a total outlay of $11, and gives entire satisfaction. The ingenuity which characterizes this novel invention crops out everywhere on the Jasperson farm, in the locks, gates, fences, and implements, and in one irrigated field there is a remodeled turbine, described on page 65, so well made as to be indistinguishable from the original mill.

Regular shopmade mills supplied water for his house and stock, the homemade mill being used wholly for driving machinery. Unfortunately means were not at hand for measuring the true efficiency of this two-fan turbine, but for practical purposes it may be said that it drove the cornsheller and feed grinder with ease. It seemed equivalent to about 1 horsepower.

HOLLAND WINDMILLS.

The Holland mills, with their four slatted fans covered with cloth sails, are so familiar in art that descriptions are unnecessary. However, as introduced into the Great Plains, they have undergone many changes and modifications, and the resemblance is sometimes lost. As viewed in pictures, the great fans are mounted on massive supports. In Nebraska, however, they sometimes stand on slender, spindling towers. They are frequently mounted upon milk houses, corncribs, wagon sheds, and barns. Their identity is further obscured at times in that the customary four fans are replaced by six or eight, and the familiar duck sails by wooden ones.

Some of the strongest and best mills in the State are modifications of these old Dutch mills. Though the picturesque mountings and settings may be wanting, their efficiency and serviceability are not. The smaller Dutch mills stand on towers, the medium-sized on small outbuildings, and the large ones on barns. In size they range from the smallest, 10 to 12 feet in diameter, through medium-sized mills, 15 to 20 feet in diameter, to the largest, which measure 36 feet.

The great Holland mill of August Prinz, 1 mile east of Chalco, Sarpy County, favorably situated as it is for observation from passing trains on the Burlington Route, has become a familiar landmark to travelers on that road (see Pl. XVIII, *A*).

The Prinz mill rises high above the surrounding grove, which, though but twelve to fourteen years old, completely shuts in the house and farm buildings. A closer view shows the large mill, with fans describing a circle 36 feet in diameter, mounted securely upon the large shed which constitutes corncribs and wagon shed, while at the house is seen an 8-foot Gem mill which pumps water from a 40-foot well to the house and stock trough. As a precaution against accident and against insufficient wind velocity, the owner has a horsepower device with shafting and pulley, which can instantly be attached to the house pump.

Ordinarily the small windmill is able to supply ample water for the

A. HOLLAND OR DUTCH WINDMILL OF AUGUST PRINZ, NEAR CHALCO, NEBRASKA.

B. SIX-FAN HOLLAND OR DUTCH WINDMILL OF HENRY BORMANN, NEAR PORTAL NEBRASKA.

use, for 80 steers, 20 milch cows, 10 horses, 125 hogs, and other stock. cordingly the large mill has so far been employed solely for the pose of grinding grain, although it can be easily geared to raise er as needed. In the amount of grist is found an easy measure of efficiency of this mill, which owes much of its merit to the fact t its projector had built mills in Holland before emigrating to this ntry in 1871.

Vith the ordinary wind of winter, when the mill is particularly in , the capacity of this mill is 200 or even 300 bushels of ground in a day. It drives an 8-horsepower feed grinder with greater ed than horses could. It elevates the grain and grinds and disrges the grist automatically, demanding no immediate supervision, le the men are engaged about the customary duties of the farm. th a good wind it is unnecessary to use more than two sails, which e all the power that is necessary for ordinary work.

'his being a large mill, heavy gear wheels and driving wheels, cougs, brakes, etc., were necessary, and these were procured in Omaha l Chicago. The total cost of the mill was $150. While this may ear to prospective builders a considerable sum, it is not prohib-'e. Against this sum must be balanced the efficiency of an orsepower plant, the fact that the mill requires little or no superendence, and that the grain is ground at home, requiring no exditure of time and money in hauling to and from the mill. A dmill so well built is capable of rendering service for twelve to een years.

Iere, as elsewhere, the author finds that those farmers who have ingenuity to invent and build mills have well-kept farms, the best es and fences, improved and excellently kept buildings, and an of unmistakable prosperity. In twenty years the proprietor has ome possessed of 320 acres of fine land set with hedges, groves, l orchards; of herds of well-bred stock and fowls; of substan-, convenient, and well-regulated houses, barns, cribs, tool sheds, l poultry houses, and of all necessary farming implements and icles. The author has driven for many miles through this favored icultural region, and scarcely less can be said of any farm visited. y are large, well kept, improved, and free from mortgage. This ut the beginning of the great windmill area of the State, which nds thence westward for 500 miles in close proximity to the Platte ley.

n the farm of Henry Bormann, near Portal, in Douglas County, ut 3 miles east of the August Prinz place, stands an important l of home production, which, like the Prinz mill, its progenitor, is ndmark familiar to travelers on that branch of the Burlington l Missouri River Railroad. It is essentially a Dutch mill, but with instead of the customary four fans, which describe a circle 19½ t in diameter. Making allowance for customary overestimates, its

true efficiency must be between 4 and 6 horsepower, and will run higher when the mill is full rigged. The surprising part is that it runs the grinder without full-sized canvas sails, its designer and builder finding that it was easier, handier, and amply efficient to use wind boards instead. These wind boards are simply thin ¼-inch boards about 7 feet long and 1 foot wide, set at an angle on each arm. They are quickly set in place and secured by wooden buttons. In a strong wind but three of these boards are used.

The capacity of this mill varies according to the wind, from 75 to 100 bushels of ground feed a day. By purchasing shafting, belts, pulleys, bevel gear, etc., at an abandoned elevator, and by making patterns for the revolving head and other parts and having them cast in Omaha, the cost of this mill amounted in all to only $50. Considering that it is well built, that it should last ten to twelve years, that it grinds all the grain for the stock and is capable of pumping and driving other machinery, there is again a decided balance in favor of the homemade mill.

During the summer months when the cattle are at pasture the mill is not in operation, so that the author made no attempt to test its efficiency, believing that the 6-horsepower grinder was a sufficient measure of its strength. This, like the Prinz mill, is so geared as to be useful in driving other machinery or in pumping water, as occasion demands.

TOWERLESS TURBINES.

It is doubtful if there is a better general example of the towerless turbines than the one across the Platte, some 20 miles south of Gothenberg. This simplified mill consists merely of a wheel without tower, axis, crank, or other working parts. The axle of an old wagon, with spindle, thimble, hub, and wheel intact, was bolted to beams on the south side of a barn, fans were nailed at a slant to the spokes, and a bolt was driven in one edge of the hub with an eccentricity of 3 or 4 inches, to which the pump rod was attached. The mill pumps water, but is dependent, of course, on south winds. From this simple form there is every conceivable gradation to the best shopmade steel mill, made of the finest material, and wrought with such nicety and precision as to return 90 per cent efficiency.

STATIONARY TURBINES.

The next higher type of the turbine is but little more specialized. It has a tower, usually of poles, a crank and pump rod, and four or more blades or fans. These constitute the whole of a mill which is considerably more efficient than the extreme simplicity of its working parts might imply. These are commonly built without expense, for the crank, which is the only piece demanding outlay, is inexpensive if bought first hand, and is usually supplied from old machinery; and

A FOUR-FAN STATIONARY TURBINE WINDMILL OF FRIEDERICH ERNSTMEYER, NEAR GRAND ISLAND NEBRASKA.

B SIX-FAN STATIONARY TURBINE OF FRED MATHIESEN, NEAR GRAND ISLAND, NEBRASKA.

the crank arms are attached to which the wooden blades are nailed. ıe pump rod is often but a sapling. The axis runs on wooden bearıgs, lubricated occasionally with axle grease. The tower is built of ı lumber, usually of poles. Such mills are numerous. Occasionıy these mills run on excellent bearings, the builder having detached rtain framework with its journals and crank from old machinery, ›lting them bodily to the tower, attaching arms to the axis, a pump d to the crank, and once in a while a brake to regulate the speed the fans.

A mill of this kind (see Pl. XIX, *A*) used by Friedrich Ernstmeyer, Grand Island, for pumping water for his stock, was especially well ıilt, and cost only 32 cents—for a 16-foot board for the fans. It as made of the oak frame and sickle driver of an old mower, which as bolted bodily upon the cottonwood tower. This is an 8-foot heel, with pine board fans 12 to 14 inches wide by 4 feet long. An ıgenious brake was made by securely wedging an old cultivator wheel › the axis, and a set of springs and levers were so arranged as to ress a shoe of leather against the wheel, thus retarding or stopping ıe mill as desired.

In the stock field of Fred Mathiesen is a six-fan set turbine (shown ı Pl. XIX, *B*), which, though very crude and rustic, runs nicely in its ıopmade bearings—the frame and journals of an old self-binder—and ›st only a few cents, for welding an extension to the axis and for ght rods with which to brace the arms. The brake is nothing more ıan a fence post, which can slide forward between the fans to stop ıem and back again to put the mill in gear. The pump rod is a nall sapling. The diameter of the wheel is 8 feet and the stroke 6 ches; total cost two or three dollars. The turbine is used for ıtering stock.

From these elementary forms, which are too numerous to allow tailed description, we pass to the set turbine, with many fans. A pical example, selected from many, is the mill built by Janak 'os., of Sarpy Mills, Nebraska.

First attempts at designing and building mills often give results ıich warrant larger undertakings, and one may see the first, the cond, and the third mill by the same designer, each an improvement the one before. It is interesting to note this advance, which is ırked by improved and enlarged designs and by superior material d make. An excellent example of this is furnished by the Janak 'os., the elder of whom arrived from Bohemia three years ago (in 96). Seeing that it was important for a neighbor to supply, in a given ısture, water for about thirty head of cattle, he immediately built a rbine mill so simplified that it consisted merely of a 10-foot wheel ade of weatherboarding, braced and wired together, mounted on an is with a 3-inch crank, which ran in journals of wood, bolted to the p piece of the tower (see fig. 16). There was no need for a revolv-

ing head or vane, for this was a stationary turbine, with fac the south, and with its tower well guyed in three directions by wire. This mill cost altogether between $3 and $4, and at tl is sure to give three or four years of satisfactory service, in to three years' service already rendered.

On the farm where poles may be cut for the tower and old is at hand, the expense of a 10-foot stationary turbine mill above may easily fall within $2.50 or $3. These are comme the attention of those needing cheap mills, especially to th have material on hand. Here t and driving wheels of discard ers may be put to advantageo

This crude wooden mill w an attempt by the Janak Br something larger, better bu more complex in its parts. T is a steel mill 14 feet in diame galvanized-iron fans, mounte revolving head upon a 35-foot tower by the side of the bla shop of the Janak Bros. T built wheel was spinning a sound or vibration, and wi shop the emery wheel, gri drill, bellows, lathe, and other ery, together with the pum driven as steadily as thoug was the motive power.

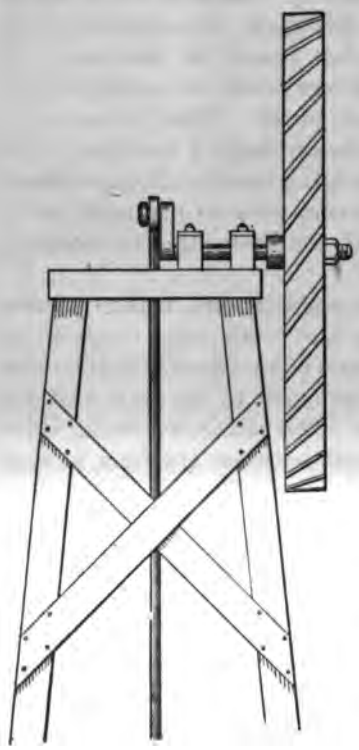
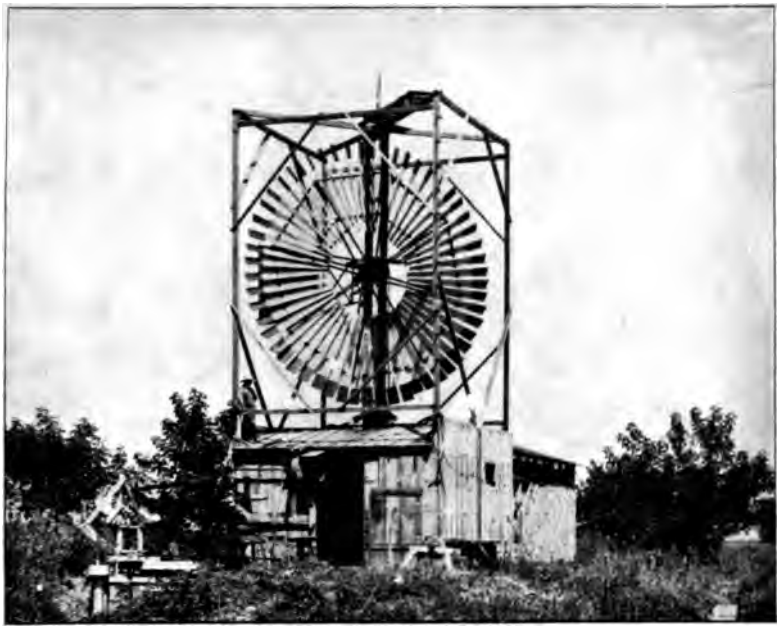
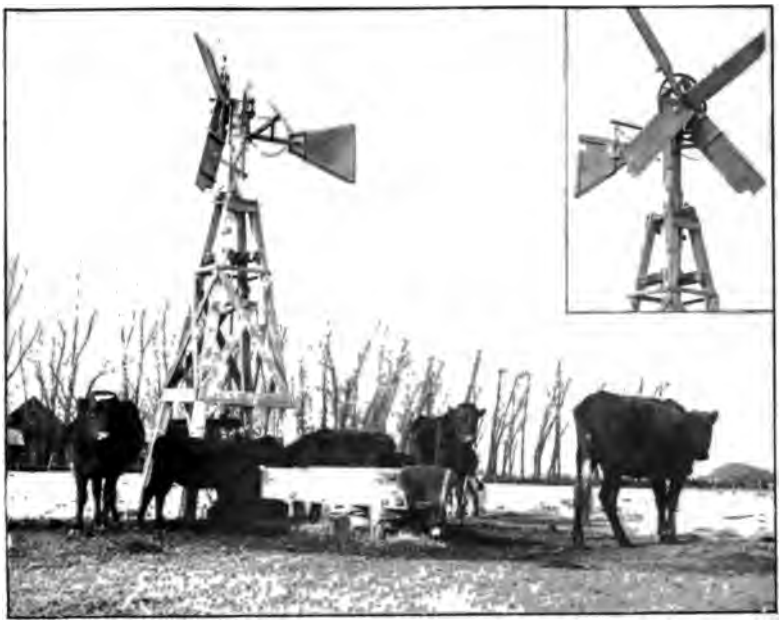


FIG. 16.—Stationary turbine designed and built by Janak Bros., Sarpy Mills, Nebraska.

Their prestige as blacksmi won largely by the windmil not only drove their machin evidenced their ability. Th well as it worked, was yet inc a fortunate circumstance, as trates the fact that in a grea machinery refinements and ries are not essentials. The mi a rudder or vane, which necessitated climbing the tower and pr wheel face to the wind with a lever. This, however, in a regic the prevailing wind is so constantly from the south, occasic little inconvenience. At the same time this shows the pro builder that he can simplify the working parts of his mill an its cost without materially affecting its efficiency. Later on, and means allow, vane, automatic regulators, and other parts added at will. In the meantime the owner has the use of an mill in which but little cash or time is invested, and thou



A. GIANT TURBINE BUILT BY J. M. WARNER, NEAR OVERTON, NEBRASKA.

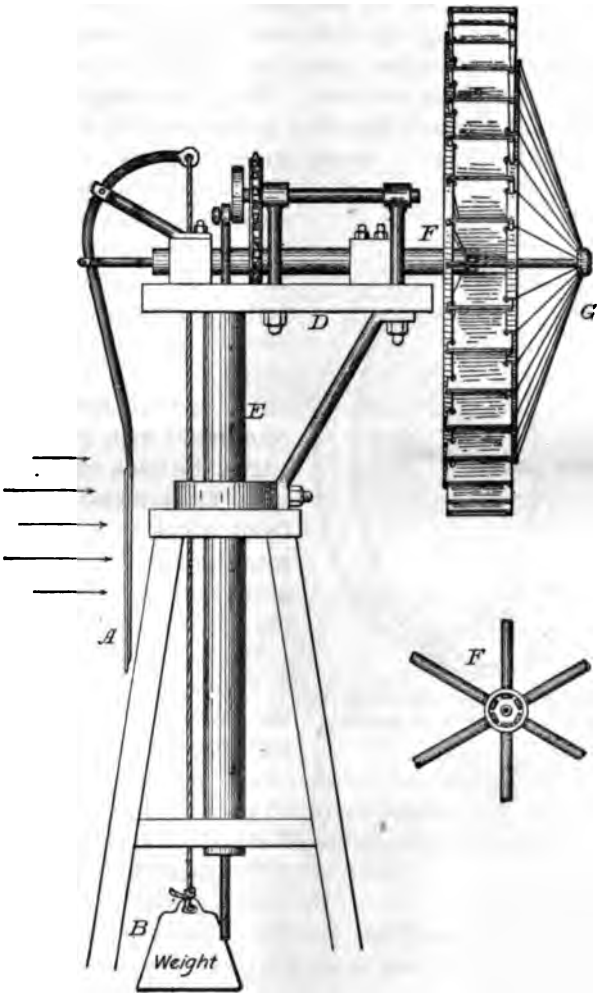


B FOUR-FAN GEARED TURBINE BUILT BY HENRY BOERSEN NEAR GRAND ISLAND, NEBRASKA.

enient it seems far wiser to have a mill like this than to be driven the undertaking by its complexity.

VANELESS AUTOMATIC TURBINES.

e vaneless automatic homemade windmill of W. F. Baldwin, of worth, Nebraska, when visited September 12, 1898, proved to be



—Sketch of homemade steel turbine of W. F. Baldwin, Ainsworth, Nebraska. *A*, Regu- : fan and lever; *B*, Weight holding the mill in gear; *D*, Platform revolving about gas- axis *E*; *F*, Windmill head with gas-pipe arms.

f unusual interest (see fig. 17). A principle seems to appear in nill not thus far seen in other mills.

Baldwin, who had formerly been engaged in several windmill anies, and had thus acquired experience, considered it a piece of y construction that shopmade mills must be subjected to the

fury of the wind before they begin to throw themselves out of action. This is a heavy and apparently an unnecessary strain, and to obviate it Mr. Baldwin so arranged his mill that the regulator receives the force of the wind before the fans. The regulating rudder (see fig. 17, *A*) is counterbalanced by a paint keg filled with sand; the rudder, thus becoming sensitive, reacts and responds to every varying breeze, constantly throwing the fans in and out of the wind. When the keg is removed the lever, falling of its own weight, pushes against a rod passing through the hollow axis, and thus sets each fan in the wheel edgewise, catching no wind. When the weight is applied each fan is thereby set to catch the wind to the best advantage. Between these two points there is every gradation, the blades constantly turning and adjusting and accommodating themselves to every breeze. Nine mills of this kind have been built and set up on farms around Ainsworth, and their owners are enthusiastic in their praise.

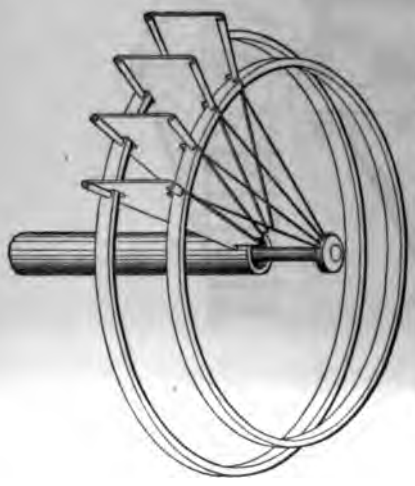


FIG. 18.—Method of regulating the fans of the homemade steel turbine of W. F. Baldwin.

The galvanized iron blades are reinforced with heavy wire on the edges, the back edges being hinged to a fixed metal circle, and the front edges to a slightly movable rotating one, which turns the fans according as the adjusting rod moves forward or back.

The working parts, consisting of a 2-inch gas-pipe axis to which the fans are attached, carrying sprocket wheels geared in the ratio of three revolutions to one stroke, were supported on a small platform, braced by rods, which revolved about a 3-inch gas pipe fixed in the tower. The tower consisted of staight cottonwood poles, bolted to anchor posts in the usual way. The axis runs on friction rollers, like the ordinary grindstone. By using pieces from old machinery the cost of this trial mill was but $5. It has been in service pumping water for the house and stock for three years.

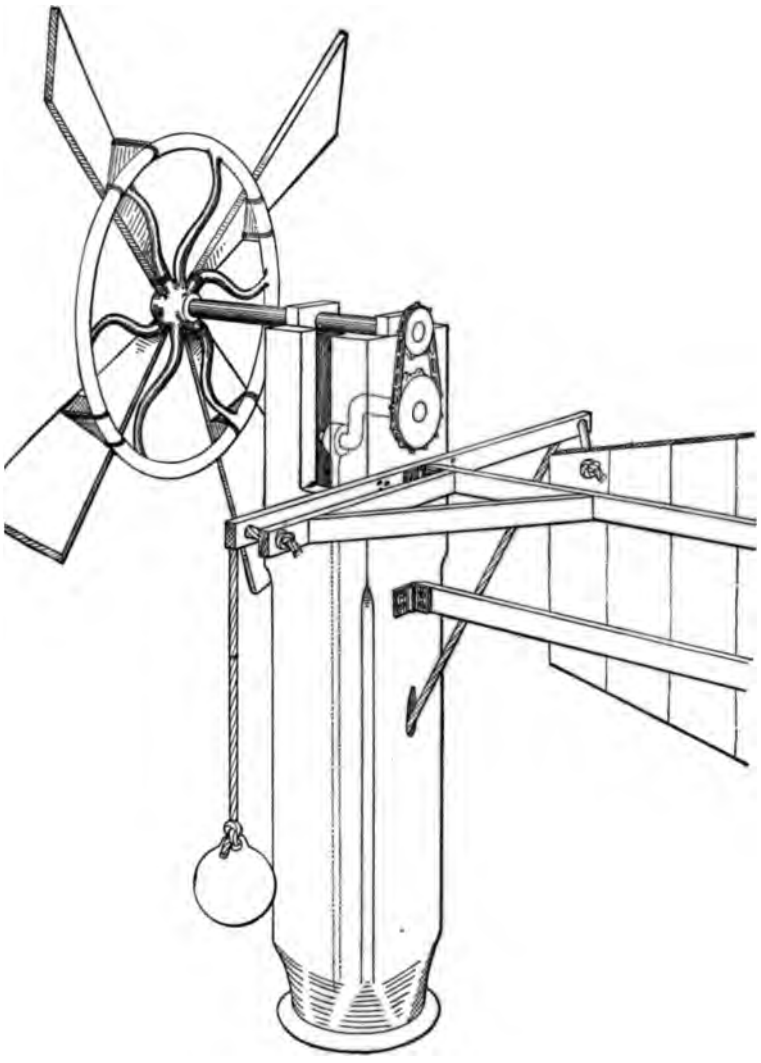
GIANT TURBINES.

The giant turbine of J. M. Warner, 4½ miles southeast of Overton, Nebraska, is one of a size rendered possible by the method of mounting it inside the tower rather than upon it (Pl. XX, *A*). This arrangement so far extends the base of support that the tower can probably never be overturned, except by winds that would move buildings. In addition it is securely guyed in four directions by

A. RECONSTRUCTED WINDMILL OF E. M. SEARLES, JR., AT OGALLALA, NEBRASKA.

B. IRRIGATING POND AND RECONSTRUCTED WINDMILL ON FARM OF ELMER JASPERSON, NEAR ASHLAND, NEBRASKA.

y twisted wire, anchored at a distance. This giant turbine, ı has no rival in size or strength, is an efficient innovation. It ıls the machinery of a 4-horsepower feed grinder. However, ·ork is done with less dispatch than by four horses, and Mr.



–Method of construction of four-fan turbine mill of Henry Boersen, near Grand Island, Nebraska. General view on Pl. XX, *B*.

er is disposed to attribute to the mill an efficiency of 3 horse- · and possibly a fraction more.

ıddition to grinding, this mill runs the grindstone and other ınery by means of a system of overhead shafting with pulleys elts. It can also be connected to a walking beam, which drives

two pumps with a 12-inch stroke, one having a 5-inch cylinder, the other a 4-inch cylinder. These are too small for the mill, as Mr. Warner finds, and 6-inch cylinders should be substituted. The lift is but 7 to 8 feet, and the endless chain and buckets might replace the pumps with marked advantage. No reservoir has yet been built, but with one Mr. Warner estimates he could irrigate 20 acres sufficiently for that region. As it is, he has successfully irrigated 8 to 10

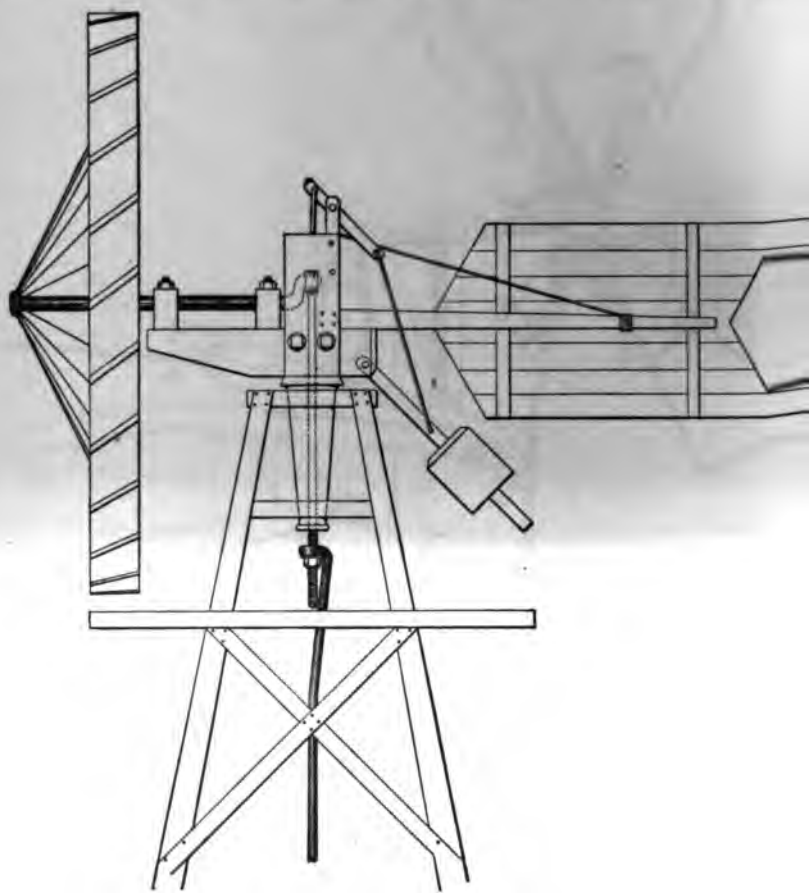


FIG. 20.—Homemade turbine mill of Lewis Jardee, of Newport, Nebraska.

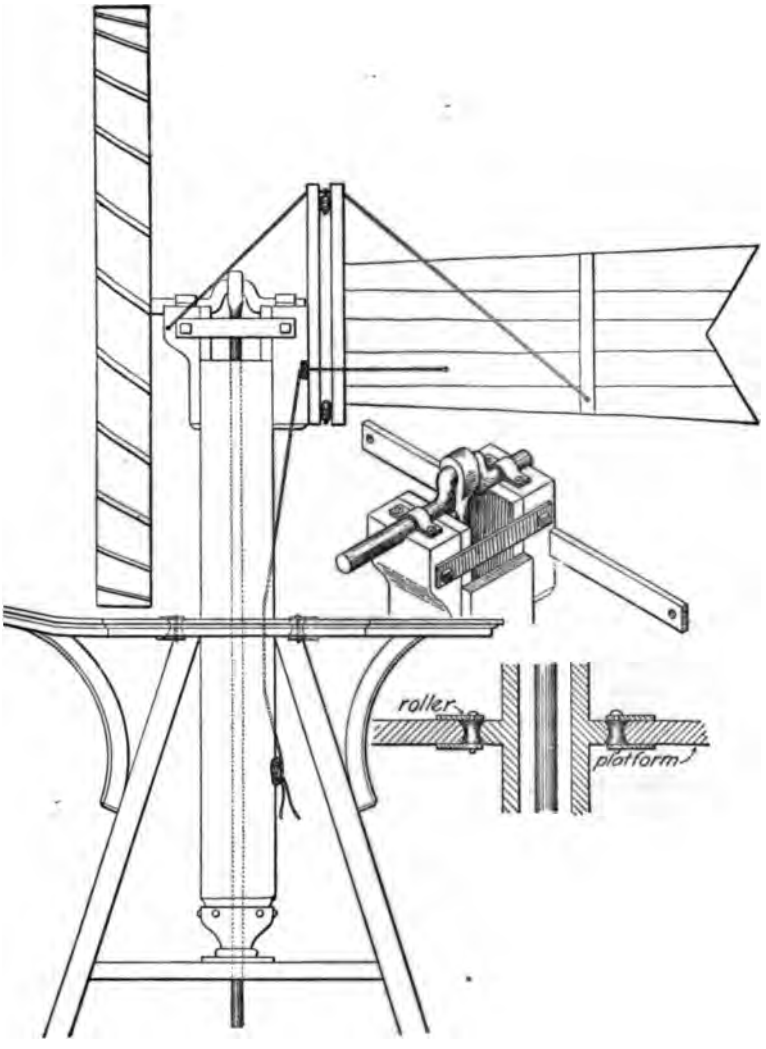
acres of alfalfa and 6 to 8 acres of corn. The mill is large, and i cost, about $60, is not disproportionate to the work performed. large rudder, held in place by a weighted nail keg, guides this gi*a*r wheel, which runs on a 2-inch iron axis, supported by a vertical re tangular frame. This principle is apparently new and worthy o development.

Plate XX, *B*, illustrates a four-fan geared turbine designed and built by Henry Boersen, near Grand Island, Nebraska. The head of

A. RAILROAD WATER TANK AND WINDMILL.

B. ELEVATED TANKS FILLED BY WINDMILL FOR TOWN SUPPLY; USED AT FAIRMOUNT, FILLMORE COUNTY, NEBRASKA.

1 old wooden pump constitutes the revolving parts, while the fly-. heel and sprocket wheels of an old cornsheller were used for the iving parts. But few bolts or screws were used, the parts being ry ingeniously wired together. Examination of fig. 19 will make 3 working parts and plan of rudder apparent. The wheel is 8



—Side view and details of revolving parts of homemade turbine windmill of W. F. McComb, Grand Island, Nebraska.

in diameter; cost of mill, $2; cost of mill, pumps, and trough, . The pulleys over which the gear ropes pass are made of s. This turbine raises water from a shallow valley well 7 or 8 and supplies 60 head of cattle. The timber shown in the back-ıd is 26 years old.

The homemade windmill of Lewis Pardee, Newport, Nebrasl shown in fig. 20, consists of the thimble of an old wagon—on whi the mill turns—to which are bolted for the driving parts oak suppo detached from an old reaper. The mill pumps about 500 gallons hour, or 12,000 gallons in 24 hours, and cost $6.

Some homemade mills are such close imitations of the shopmad that the casual observer fails to see the differences which are appare on closer inspection.

The mill of W. F. McComb, of Grand Island, shown in fig. 21, is example. In appearance it is a shopmade mill; in fact every porti of it is homemade. The fans are of metal, the rudder of light woo hinged, and adjustable from the ground to throw it in and out of ge like ordinary mills. The mill acts directly on the piston, giving 10-inch stroke. The head and axis are supported on a vertical woode box, which, guided by friction rollers set in the platform of the towe revolves upon a conical casting at its base. It is a 10-foot whee pumps water by a 3-inch cylinder into the tank, a lift of 44 feet, a irrigates the garden and lawn. It cost possibly $20, and has r since the spring of 1897.

RECONSTRUCTION OF WINDMILLS.

In the provisional classification of homemade windmills, the reco structed mill is placed next in importance to the shopmade mill.

There are great possibilities here, which have been and may be tak advantage of many times. In every community are neglected fallen mills and towers which might be reconstructed at a mere nominal cost, either by the owner or by the purchaser of such id property. The essential parts are often intact, and it is a simp matter to substitute homemade fans and rudders for those missin Many mills are standing in disuse year after year, while rough boar nailed to their bare arms would start them going.

Many take advantage of this opportunity, and that others may reminded of the possibility a few reconstructed mills will be figur and described, in the belief that this small number will sufficient represent all.

Reconstructed mills are to be found in every county in the Sta but nowhere are there better examples than at Ogallala, in weste Nebraska. Within the town at least five reconstructed mills are use, pumping water mostly from shallow wells.

At the livery and feed stable an old mill which has lost all its fa and its rudder has been so rejuvenated by simply nailing 6-in boards to the bare arms that the mill is pumping water for horses. This entailed no expense and but little time and labor.

Near by stands a reconstructed mill still doing duty in pumping the house and lawn, though furnished with six rough blades. T mill which formerly occupied its place upon the substantial tower h

ARTIFICIAL PONDS OF THE MOULTON ICE COMPANY, LINCOLN, NEBRASKA SUPPLIED WITH WATER BY TWO TURBINE WINDMILLS

been racked by gales and storms, and had been allowed to lose its woodwork and so fall naturally into disuse. However, the essential parts remained as a base, to which homemade parts could readily be attached without cost. (See Pl XXI, *A*.)

Within a few blocks is to be seen the most interesting one in the place. It stands on a slender steel tower, like a veritable toy mill, but it pumps water for the house, for four horses, and for the irrigation of the lawn and garden.

The success of this toy turbine is due in a measure to the fact that it is a reconstructed aermotor. Two sets of galvanized fans and rudders had been demolished, and the last time the iron fans were replaced by thin boards 5 inches wide and 2 feet long wired firmly to the six iron arms. The rudder was left off; accordingly, instead of standing face to the wind, it swings around automatically (because slightly eccentric) and stands back to the wind. Thus the motion is reversed, and the fans run backward, but with no apparent disadvantage.

On measuring the wind velocity with an anemometer, and measuring the water pumped, the following results were obtained: In a 15.5-mile wind this toy mill lifted from a shallow well (12 feet deep) a trifle more than 270 measured gallons in an hour, or at the rate of 6,500 gallons in twenty-four hours, its efficiency being one-eighth horsepower.

Near Kearney is a reconstructed mill whose arms have been slightly lengthened, and to their extremities were nailed light fans made by boys of the farm from the thin sides of boxes. Although this gave a rough and unnatural looking exterior, the small irrigating reservoir stood full of water. The admirably constructed mill of Elmer Jasperson near Ashland, Nebraska (shown in Pl. XXI, *B*), seems to differ in no respect from the best shopmade type, although it had been a total wreck. It was purchased for $3 as it lay on the ground twisted and broken, and hauled to the Jasperson place. At an additional outlay of $7 the bent parts were straightened, the tower rebuilt, and the mill reinstated as good as new, so far as outward appearance and action are concerned.

SHOPMADE TURBINES.

The highest type is the shopmade mill, which is so closely allied to every well-regulated Western home. These mills are inseparable features of every landscape, of every farm, village, and town. One may count as many as twenty-five or thirty mills in view at one time from the car window in passing, and thirty or forty in any town. These mills have given to the country home many of the comforts of the city. They enable small towns to have water systems with standpipes, water mains, and hydrants, a satisfactory domestic water service, and a supply with ample pressure for fire protection at a cost much below that for similar water service in a city.

The windmill and tank are the conspicuous and characteristic land-

marks of every siding and station in the prairie. (See Pl. XXII, *A*). Asylums, homes for soldiers, orphans, blind, and feeble minded, and other public institutions in rural districts isolated from city conveniences depend on the windmill. The town pump has given way to the town windmill and tank, which easily furnish water for the public watering trough and the public hydrant.

In villages too small to assume the expense of standpipe, water mains, and hydrants, pressure for fire protection is often obtained by carrying the tower of the public tank as high as need be, and mounting upon it a second tank for use in case of fire. (See Pl. XXII, *B*.) Precaution is generally taken to augment the mill with a good steam, gasoline, or petroleum engine for use in emergency, or in case of a continued calm. This makes an excellent and cheap system. The mill is the main dependence, the engine being pressed into service but occasionally.

In many towns and cities the turbine is used to pump water for fish ponds and ice ponds. In the smaller towns the irrigating pond of summer is turned to good account in winter, in furnishing an ice harvest. In Lincoln, the Moulton Ice Company harvests its ice from three artificial ponds supplied with water by two turbine mills. These same ponds are stocked with several thousand fish. (See Pl. XXIII.)

Under the refining influence of the windmill, the pioneer school house, first of sod, then of lumber, begins to lose some of its utter barrenness, and sod, trees, and shrubs begin to grow.

ORIGINAL USES FOR SHOPMADE WINDMILLS.

The shopmade mill is often harnessed to homemade water lifters of unique and original design. These are as interesting as the homemade mills themselves, and are worthy of a special report, which the author has in preparation.

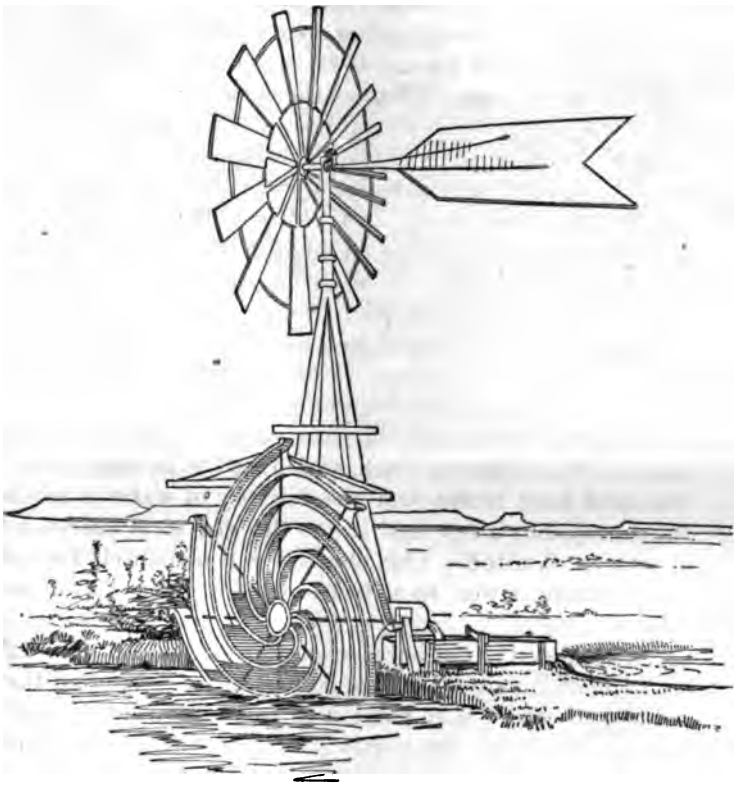
One or two examples will illustrate this group sufficiently for the present.

At Milford, on the banks of Blue River, may be seen a large mill and tower (see Pl. XXIV), now in disuse, geared to run an endless chain of 34 buckets, each holding 4 gallons. This method of raising water is one of the oldest as well as one of the best. However, in this instance, the mill is so completely overtaxed as to be rendered useless. Smaller buckets and lighter machinery would doubtless give satisfactory results. The possibilities of this kind of irrigation are great and every river bank shows some kind of an attempt to pour the water upon the land. Some of these water lifters are driven by the current, some by windmills, and some by horse power or steam power.

At North Platte the natural order of things seems somewhat reversed through the use of a tympanum wheel, run by a large aermotor instead of by the current. (See fig. 22.) The tympanum is primarily

WINDMILL AND WATER ELEVATOR ON BLUE RIVER, NEAR MILFORD, NEBRASKA.

ırrent wheel, but in this case, there being no current, its place was plied by a 12-foot aermotor, which caused the tympanum wheel revolve once a minute in a good wind and to discharge at each olution 8 barrels of water through the hollow axis, lifting it 7 feet l irrigating 60 acres. This tympanum is beautifully built and



2.—Two-foot tympanum water wheel operated by 12-foot aermotor; invented and built by David Thomas, of North Platte, Nebraska.

ırately constructed, but it is not at all unlikely that buckets or n pumps would give equal results at less expense. The cost was).

OTHER FORMS OF WATER LIFTERS.

nticipating a future chapter on the water lifters of Nebraska, the hor, knowing the demand for hints on all such matters, can not ain at this point from mentioning some other water lifters, though ign to the immediate subject. The principal water lifters other n the windlass, hand pump, windmill, horse-power, gasoline, petro-n, and steam engines are the endless chain and buckets, current els of all sizes and makes, Archimedes screws, jacketed screws ning at high speed, etc.

he endless chain and bucket, of which there are many makes, is an

A. THIRTY-FOOT CURRENT WATER WHEEL ON BRANCH OF HAT CREEK, SIOUX COUNTY, NEBRASKA.

B. THIRTY-FIVE-FOOT CURRENT WATER WHEEL NEAR HOT SPRINGS, SOUTH DAKOTA.

seems better economy for the busy and well-to-do farmer to purchase these quadrants outright from his nearest windmill house, but for those who can better afford to spend energy and time than money the wooden angle block (see fig. 23) will prove an acceptable substitute for a better article.

If some of the surplus energy of the wind during certain seasons or during the more windy hours of the day could be conserved, it would apparently equalize matters to that extent. The best means to that end at present is literally to bottle it. That is, the windmill must compress the air into stout iron cylinders, or bottles, to be drawn

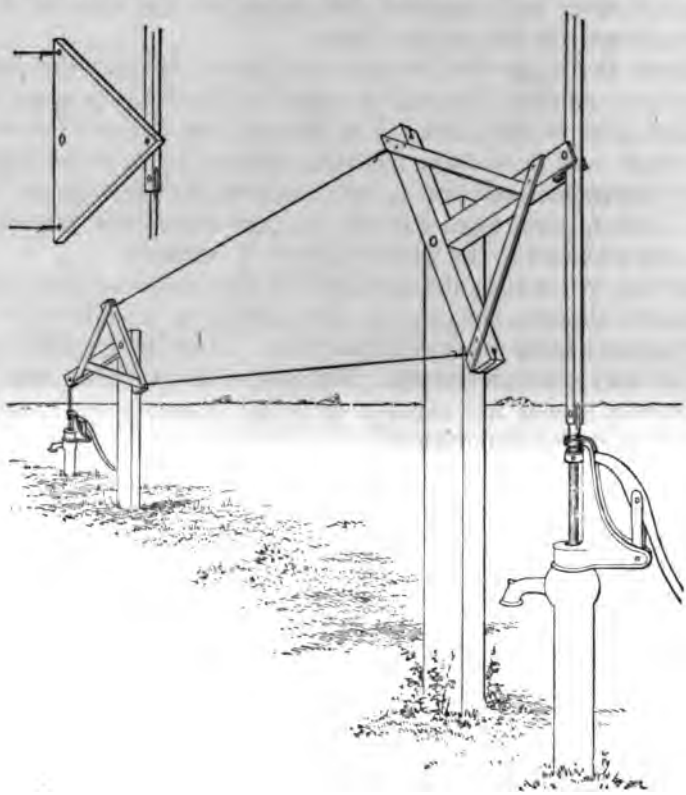


FIG. 23.—Transmission of power of windmill by oscillating wires.

off and used in any way desired. A small stream of compressed air admitted at the bottom of a tubular well often causes the water to flow as if it were an artesian well.

In many of our artesian regions there are countless spots in which water rises under pressure—and in that sense is artesian—but still does not flow over the surface. Such wells, treated to a small stream of compressed air, would flow vigorously like small "spouters." So far as can be learned nothing of this sort has yet been attempted in Nebraska, although it is contemplated. The park board of Omaha

has long considered this as a means of converting certain negative artesian wells into positive ones for the improvement of the park system of the city. In the Great Plains, where there is so much energy stored in the winds, a great natural resource seems to be going to waste for lack of development. It may be conserved by using the windmill to charge storage batteries.

PRECIPITATION IN NEBRASKA.

The climate of Nebraska is characterized by a low percentage of cloudiness, by a correspondingly large amount of sunshine, and by a dry and healthful atmosphere, whose chill in winter is less severe and whose heat in summer is less oppressive because of the low humidity.

Situated far inland, there are no great bodies of water to furnish evaporation. Little moisture finds its way from the Pacific slope, because of the Rocky Mountains. The rain-bearing winds come from the southeast, and the ultimate source of precipitation in Nebraska is the Gulf of Mexico. Although rainfall is rather limited, there is compensation in the fact that it comes at the season when crops are growing, and also in the fact that so great a proportion is absorbed and retained in the soil.

Professors Swezey and Loveland, in Bulletin 45 of the Agricultural Experiment Station of Nebraska, have shown that—

> f the 23.33 inches of annual rainfall in Nebraska 16.08 inches, or 69 per cent of he entire amount, falls during the five months of the growing season, April to ugust, inclusive. In order to show how we compare in this respect with other tates the following table is introduced. It shows what per cent of the total early rainfall occurs in these same five months in other localities.

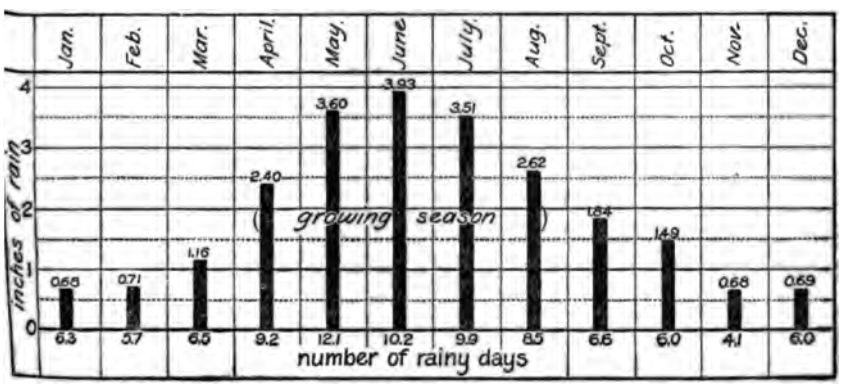


FIG. 24.—Monthly precipitation in Nebraska.

Rainfall during the growing season in various localities.

Station.	Pe
St. Louis, Mo	
Cheyenne, Wyo	
Dodge City, Kans	
North Platte, Nebr	
Omaha, Nebr	
Huron, S. Dak	
St. Paul, Minn	
Duluth, Minn	
Davenport, Iowa	
Keokuk, Iowa	
Nebraska in general	

It thus appears that the States of Nebraska, Kansas, Dakota, and Wy with their none too plenteous supply of rainfall, have, on the other ha advantage over the States lying farther to the east that a large percentage rainfall occurs in the growing season, when it is most useful, and that a eastward the percentage gradually falls off, particularly toward the southe in other words, in the direction toward which the actual amount of increases most decidedly; so that if we compare the rainfall of the growing alone in the different localities, Nebraska does not appear in so unfavo light as her small yearly rainfall would indicate.

Table showing the annual precipitation in Nebraska and other State

States.	I
Indiana, to 1894	
Illinois	
Iowa	
Kansas	
Kentucky	
Michigan, to 1896	
Missouri, to January, 1895	
Nebraska	
Six New England States, to 1896	
New York	
North Dakota	
Ohio, fifteen years to 1896	
South Dakota, to 1896	
Wisconsin	
Wyoming, five years to 1896	

SURFACE WATER AVAILABLE FOR IRRIGATION.

The first writer of prominence in Nebraska who advocated irrigation was Mr. Lewis E. Hicks, at that time professor in the University of Nebraska. His paper aroused such vehement opposition from the country press of the State at large that his position in the university was threatened. His opponents even went so far as to threaten the university itself. Hon. William R. Akers, secretary of the State board of irrigation, was among the first to put the question to a practical test, although in the face of open and avowed opposition, by building an irrigation plant in the fall of 1887. Since that time the growth of irrigation in Nebraska has scarcely been surpassed elsewhere; many miles of ditches have been built and many acres of otherwise sterile land brought under cultivation. There are at present in the office of the State board of irrigation 1,000 claims and applications, covering a total acreage of more than 4,375,321 acres for which water is claimed, the increase in land values amounting to ten to twelve million dollars.

Irrigation, wherever it is practicable, settles the matter of subsistence, for it supplies the one and only lacking soil constituent. But expectations must be kept within the bounds of reason, for there is a natural limit to this important element of our soil fertility, because the total supply of available surface water is sufficient to cover but 5,723 square miles, according to careful computation made by Prof. O. V. P. Stout—an area about equal to the combined areas of Scotts Bluff, Banner, Kimball, and Cheyenne counties. Though large, the relative insignificance of this tract as compared with the 77,000 square miles of the State is apparent. This area may be increased somewhat by pumping water from underground sources, which promises most encouraging results.

The development of windmills and other water lifters of all sorts for purposes of irrigation has been also almost as phenomenal as that of the growth of ditches themselves during the last four years, and, because of their wider applicability, bids fair to be of even greater usefulness.

SUPPLY FOR TOWNS AND CITIES.

Surface water, which is an important source of city supply in many of the Eastern States where rivers are perennial and lakes abound, is of little consequence for city and village use in Nebraska, for the obvious reason that few lakes (except ponds) exist and perennial rivers and streams are few. Accordingly but little surface water is furnished for cities and towns, and thus the use of water which must suffer steady and progressive deterioration and contamination is avoided.

The cities and towns along the lower reaches of streams are not condemned to the fate of using the sewage and filth contributed by

settlements above, nor of obtaining water from the same lake which receives their offal. Instead, the supply is ground water of almost inexhaustible quantity and superior quality, found in deep, gravelly soils, where extensive sheets of clay preclude the possibility of pollution by surface matter. It is safe to state that this is and must continue to be the source of supply alike for city and country homes.

Cisterns are often built to catch soft water for the bath and laundry, but the use of such water for drinking is very limited. Although the ordinary well water of most of the State is hard, it is not injurious. The hardness is due to lime in solution. Neither is the yellow and turbid water, which has given the Missouri the fitting appellation "The Great Muddy," necessarily injurious. The color is due to clay in mechanical suspension in the water, and its presence affects its appearance rather than its healthfulness. Such inorganic particles can be taken into the system without fear.

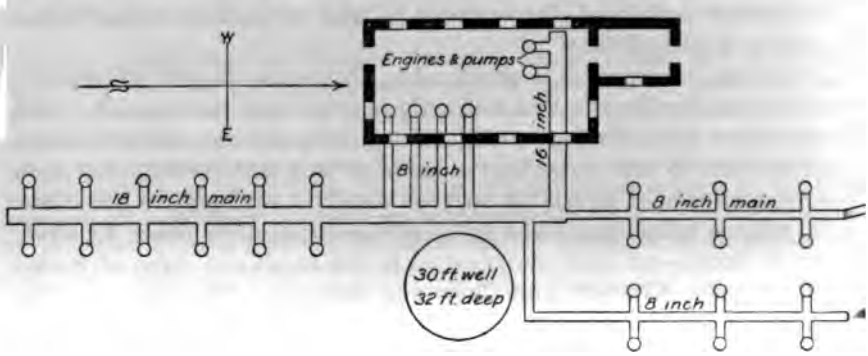


FIG. 25.—Plan of waterworks at Kearney, Nebraska.

The natural and simplest method is to draw city water supplies from streams, as is done in the case of Omaha, where the water is taken from the Missouri far above the city and allowed to stand in settling basins, whence it is pumped into the city mains. Notwithstanding prejudice against the milky color of this water, there is no reason for condemning it, for the upper reaches of this river are still so sparsely settled that the present pollution is unimportant. Interior towns far from any stream, working on the plan that if one well can supply the individual many such can supply a community, dig and connect gangs of wells. On this plan excellent water is furnished to the citizens of Lincoln, Hastings, Kearney, and smaller towns.

Kearney is in the Platte Valley, 22 feet above the level of the river, where an inexhaustible underflow can be had even in shallow wells. From one large 30-foot well, 32 feet deep, and twenty-four tubular wells a supply of water is obtained which can not be lowered and whose quality has given entire satisfaction. (See Pl. XXVI and fig. 25.) This is a source of pure water that can be depended on for years to come.

WATERWORKS AT KEARNEY, NEBRASKA.

that an equal amount of water supplied by the water company at the lowest possible wholesale water rate would cost the city $5,000 annually.

A rather novel if not unique method of irrigating by means of salt water is in vogue with market gardeners along Salt Creek. The water of this creek being too saline for direct application to the land, it is used to turn paddle wheels, which at sight might be mistaken for current wheels. Here is an example of the utilization of salt water in running undershot wheels and pumping fresh water for irrigation.

BLOWING WELLS.

One rather phenomenal class of wells found throughout a large portion of the State, especially south of Platte River, deserves particular notice, and is worthy of the critical and long-continued study which it is hoped it may yet receive. These wells are known by various names, "blowing," "roaring," "breathing," "singing," or "weather" wells, according to the widely separated communities in which they occur. It goes without saying that these wells are held in doubt elsewhere, but the fact of their existence is established beyond all question. In some communities, noticeably those of Jefferson County, all such wells are readily distinguished at a distance because of the mound of earth heaped up around the curbing and pump to check the wind. Frequently they are banked up with snow instead, and this soon becomes melted and riddled by numerous blowholes.

The attention of the author was first called to this matter by the numerous inquiries sent to his office for explanation of and the remedy for the freezing of well-protected pipes in wells at the apparently impossible depth of 30, 50, 60, 80, and even 120 feet below the surface. In every instance these were reported as roaring wells. There can be no possible doubt about the freezing of these pipes and but little doubt as to the cause.

Reports have come in from about twenty counties, distributed pretty evenly over the State, chiefly south of the Platte. The information is derived from landowners, farmers, well diggers, ministers, principals of schools, civil engineers, and students whose fathers own such wells, the only difference in the reports being that which arises from difference of observation. These accounts agree with personal observations. There are periods when these wells blow out for consecutive days and an equal period when they are reversed. This is tested with the flames of candles and by dropping paper, chaff, feathers, etc., into the casing to see it blown out with some force or drawn in. It is further stated that blowing often indicates high or low conditions of barometer, and that some wells blow most audibly when the wind is from the northwest, whereupon water rises to a higher level in the well than before; but when the conditions are reversed the air is drawn in, and in most reported wells the water is

lowered. Many observers notice a reverse of the current according as it is morning or evening, and according as the temperature is high or low. During the progress of a low-barometer area over one of these regions the wind is expelled from blowing wells sometimes violently and with a noise distinctly audible for several rods. Consequent to the following of a high-barometer area the blowing becomes rapidly less until the current is reversed, when the high-barometer area is central over the region.

Steam or water vapor rises from the curbing, melting the frost or snow for several inches around it. Beyond this the well may be encircled by several feet of frost from the condensed vapor. Shortly after the current is reversed the thawed circle freezes again. Water vapor, coming from the stratum of invariable temperature, in winter is warmer when expelled than is the outside air. This may explain the fact that the pipes, if not too badly frozen, are often thawed out when the well blows. It is said that commonly inhalation (which carries the surface temperature to the bottom of the well, thus freezing the pipes), precedes the phenomenon of exhalation (which carries vapor at the average temperature of about 56°, and sometimes thaws the frozen pipes).

Experience has taught the people that the blowing of their wells is premonitory of an approaching storm; hence the name "weather" wells. This is an entirely reasonable and correct observation, for the falling barometer signifies a change of weather. The blowing means a low-barometer area, the sucking a high-barometer area. It is interesting, in this connection, to notice that the periods of most pronounced or unusual exhalation or inhalation are coincident, respectively, with periods of exceptionally low and exceptionally high barometer areas. The author has sent blanks to owners of blowing wells, requesting them to report the days and hours when their wells begin to blow, when the blowing is at its maximum, when the current is reversed, and when the indraft is at its maximum. After observations covering two or three months have been received comparison will be made with the barometric chart.

Professors Loveland and Swezey, of the Signal Service Station of the University of Nebraska, have made observations on such a well in Perkins County, the owners recording the hour when the blowing or sucking began. These, when compared with the records of the barometer, were exactly coincident. The citizens have elaborated many explanations, some of them as interesting as ingenious. Some reason that the blowing is plainly due to the liberation of natural gas; that natural gas is from petroleum; that petroleum is the natural distillation from great coal fields, and staking their fortune on this original reasoning have spent no small sum, besides valuable time, in prospecting for coal. A few, noticing a change of current every twelve hours—that is, morning and evening—think the blowing wells are due

to tidal action of the sheet water, considering the sheet water as a great subterranean lake. They should recall that the effects of tides on the Great Lakes themselves is scarcely appreciable; what then could it be in the sheet water?

The phenomenon is most generally attributed to atmospheric pressure, which is probably the true but not necessarily the sole cause. The study of a representative section of wells in southeastern Nebraska is important and suggestive. Below 50 to 100 feet of soil and subsoil is a layer of dense, though thin, limestone about 4 inches in thickness. When this covering to the water-bearing gravel below is penetrated, water, under slight pressure, rises about 1 foot. The water-bearing layer is very porous and water is delivered through it readily. More or less air must always be inclosed in such, and especially between it and the roofing layer over the loose material.

It is plain that the air above and the air inclosed in the rock and gravel below are alike subject to the fluctuation of the barometer. If the surface air is rendered less dense by a low barometer, the air below will pass out by an opening, natural or artificial, until equilibrium between the rarer and the denser air is established, when they remain stationary. The reverse effect follows a high-barometer area. The author can not believe that this would account for the force displayed in the expulsion of air. Instead, the energy displayed seems due to the air forced out by the rising of the water below. Any force, barometric or otherwise, which would raise the water level in this layer would displace a certain amount of air. On the other hand, a lowering of the water table would admit a certain amount of air, but freedom of egress and ingress is retarded by the roofing layer of limestone, which is perforated here and there by an occasional well, and from such openings the air is expelled or drawn in. Confine this over a wide area, and it is apparent that a slight rise in water level would expel air from a well for several consecutive hours or even days. There is probably such close hydrostatic connection in the sheet water of the State that it is everywhere sensitive to differences of atmospheric pressure, and the difference is made sensible in certain localities by blowing or sucking wells. Awaiting the time when continued study shall have made exact explanation of this phenomenon possible, it is safe to attribute it to atmospheric pressure; but this is not the sole cause. The immediate effect is not so much the result of any one cause as of several. The observation is often repeated that wells blow and water rises appreciably when the wind is from the northwest. The wind is not so directly the cause as are the areas of low and high barometer, which travel ordinarily in this direction accompanied by more or less wind. The wind may, however, be the immediate cause in some cases, especially in those wells adjacent to Platte River, and an indirect cause in others. At times, when a strong wind from the northwest prevails for hours, its impact

ɣainst the river water—that is, the friction of the wind—is sufficient ı drive the shallow water of Platte River across its bed, leaving the rigation ditches, the sand bars, and the interlacing channels on the ɔrth side dry, while those on the south side are flooded. That is, the ıters are piled up here, as it were, and equilibrium is disturbed. ɔ that extent there must be readjustment. This is rendered sen- ble in the immediate vicinity by water rising in wells, at a distance ' a wave of transmitted energy, which can but affect to a certain :tent every portion of the underflow of the Platte. This may show ɜelf in an appreciable rise of water and consequent displacement of r from porous strata, and an appreciable rise over a wide area might :pel a large volume of air. Tests show that it is air, not gas, that expelled. While exact records have been kept respecting blowing ells as far west as Perkins County, those farther east in Jefferson ɔunty, probably the most numerous and best known in the State, ıve received no critical study as yet.

Mr. Cassius A. Fisher, assistant in the department of geology, was ınt to visit this region December 16, 1896, just as a low-barometer 'ea was central over this spot, and the blowing in all the wells of the ɜighborhood was most pronounced. This continued in a diminishing ;tio during the night and until noon the following day. Then the ırrent was slowly reversed consequent to an approaching high- 'essure area. Mr. J. M. Rohrbaugh, a student in the department, ports a blowing well on the farm of his father, Mr. C. W. Rohrbaugh, ı follows: The well is situated 4 miles southeast of Jansen, in Jeffer- ın County, sec. 1, T. 2, R. 3 east of the sixth principal meridian. he well was bored to a depth of 130 feet; depth of water 120 feet. blows out before storms, especially when the wind is from the north- est. It has frozen repeatedly to a depth of 120 feet, that is, to the ater level. Water froze in the pipes down to this depth three times one week during the winter of 1895, and the pipe had to be removed ıd thawed out each time. There are two such wells, one of which ıs been abandoned, and over the top of the casing has been fitted a ɜg with a hole so bored that it whistles when the current blows out. he well sucks in air during cold weather, and then it is that pipes eeze at unusual depths.

They are of such common occurrence in Jefferson County that little thought of the phenomenon. Mr. Rohrbaugh has furnished the ıthor with a map showing the blowing wells near Jansen. Mr. Cassius . Fisher reports such a well, known to him from his childhood, on ıe farm of his father, Mr. M. C. Fisher, six miles east of Fremont, Saunders County. The well was 60 feet deep, and on a hillside. hey called it the "singing" well, because the sound exactly resembled e singing or simmering of a teakettle. The blowing often continued r three consecutive days; at the end of that time water stood several et higher in the well, as they could tell by lowering the well bucket.

The "breathing" well of Joseph Henggler, of Columbus, Platte County, represents very nicely this type of wells. It has been reported in person by the owner and by at least six to eight different neighbors. They have long been familiar with the fact that the air was drawn in during certain seasons and blown out during others, and with the difficulty from the freezing of the pipes; the water escape has been lowered from 10 feet, where it was first placed, to 20 feet, then to 40, and finally to 50 feet, which was about on the water level, the well being 60 feet deep. The pipe was frozen at the depth of 50 feet. Mr. Henggler has kept a thermometer by his well, and has been able to make pretty close observations. "When the temperature stands at 32° a rise of 1° will cause a current to blow out and a fall of 1° to blow in." Finding that the well was freezing, he undertook to stop the ingoing current by banking up the well curbing with manure and straw from the barn. This was soon blown away. Then straw with a layer of earth was placed over the curbing. Finally the "imprisoned wind" blew around the curbing to such an extent that it hollowed out a considerable basin. After several years the well was abandoned and a second well dug, which has caused the owner, according to his account, almost as much trouble. In Franklin County exactly similar wells are reported. An assistant has visited and reported a well near Macon which has frozen in winter to a depth of 80 feet, because of the indraft of cold air. He also reports of the same well that when the wind is from the northwest the water is raised about 18 inches, and when in the opposite direction the water is lowered about 18 inches.

In Phelps County, 3 miles north of Phelps Center, there are blowing wells in which the current of air is out or in, according as the wind is from the north and northwest or from the south and southeast. Mr. J. F. O'Brien, engineer of the irrigation canal at Kearney, has seen these wells, and has told the author personally of them and of blowing wells found in Lincoln County. According to his account he has seen numerous wells of this type, and they are usually found in loose sand and gravel south of the Platte.

INDEX.

Page.

unty, well in 20
, well near 20
ills at 41, 59–60
eriment station at 25
water, nature of 18–24
wells in Nebraska, list of 20–23
ance, wells in 18
plate showing windmill near 52, 60
ills near 53–54, 65
W. F., windmill of 59–60
windmills, features of 47–54
s showing construction of 40, 49, 50, 51, 52
wells at 19, 21
ossing, plate showing wells at 24
at 19
n, water elevator near 68
gure showing windmill at 44
plates showing windmills near 36
mill near 37, 39
, Kans., experiment station at 25
, K. E., windmill of 45–46
wells, features of 78–82
's windmill 38–39
Henry, windmill of 62–63
rings, nature of 21
Ferdinand, cited 75
Henry, windmill of 55–56
nty, wells in 20
w, experiment station at 25
wells, features of 78–82
ll near 22
unty, well in 20
L., windmill of 37–38
well near 22
n Beach, plate showing 76
ells at 77
ity, wells in 20
H. W., deep plowing by 26
action of water 16
rous formation, wells in 19
ity, well in 21
sing, methods of 26
unty, wells in 21
ate showing windmill near 54
mill near 54–55
unty, wells in 21
County, well in 21
ing, results of 25–26
, blowing well at 82
mill at 41
ls at and near 19, 21, 22

Page.

Cozad, plate showing windmill at 38
windmill at 39
Craig, well in 20
Crawford, well at 21
Crete, water elevator near 69
Cuming County, well in 21
Current wheels, features of 69
Curtis, experiment station at 25
Cushman County, plate showing windwill in 38
Dairying, use of windmill in 29–30, 31
Dakota sandstone, artesian wells in 19
Dawes County, wells in 21
Deep plowing, advantages of 26
Dixon County, wells in 21
Dodge County, well in 21
Douglas County, wells in 20
Dust-blanket farming, method of 26
Dutch windmills, features of 54–56
Elk Creek, well near 21
Elkhorn, well in 20
Endless chain, use of 44, 66, 67–68
Erina, well at 21
Ernstmeyer, Friedrich, windmill of 57
Fairmont, plate showing waterworks at 62
Fisher, C. A., work of 81
Fisher, M. C., well of 81
Franklin County, blowing well in 82
Fremont, blowing well near 81
Fullerton, well near 22
Gage County, well in 21
Gandy, well at 22
Garfield County, wells in 21
Geiss, Jacob, windmill of 48
Gering, well at 23
Go-devil windmills, features of 35–44
Goodrich, W. W., windmill of 37, 39
Gothenburg, plate showing windmill near 52
windmill near 51–53, 56
Grand Island, plates showing windmills near 48, 50, 56, 58
windmills at and near 45, 47–48, 50, 57, 62–64
Grant, experiment station at 25
Grant County, well in 21
Greeley Center, windmill at 45
Ground water, action of 14–28
Harders, John, windmill of 50
Hat Creek, current wheel on branch of 69
plate showing current wheel on branch of 68
Hastings, experiment station at 25
water supply of 74–75

Page.
Hastings, well near 20
Havelock, windmill in 37
Henggler, Joseph, well of 82
Herman, wells at 23
Hicks, L. E., cited 73
Holdrege, experiment station at 25
Holland windmills, features of 54–56
Holt County, plate showing well in 18
wells in 19, 21
Homemade windwills, cost of 34
description of 35–64
distribution of 35, 36
types of 34–35
use of 31–34
Hood, O. P., cited 36
Hooker County, well in 21
Hooper, well near 21
Hot Springs, S. Dak., current wheel at 69
plate showing current wheel near 68
Huennecke, Diedtrich, windwill of 50–51
Hunter, David, current wheel of 69
Hyannis, well at 21
Hygroscopic water, action of 16
Iler, W. W., windwill of 37
Intensive cultivation, effects of 25–26
Irrigation, use of artesian wells in 23–24
use of water lifter in 68
use of windmills in 29–31, 39–40
water available for 73
James, William, water elevator of 69
Janak Bros., windmill of 57–59
Jansen, blowing well near 81
Jasperson, Elmer, windmill of 53–54, 65
Jefferson County, blowing wells in 78, 81
Joehnck, Henry, windmill of 45
Johnson County, artesian wells in 18
wells in 19, 21–22
Jumbo windmills, construction of 42, 44
features of 35, 42
plates and figure showing construction of 40, 42
Karr, J. W., water elevator of 68
Kearney, plan of waterworks at 74
plate showing waterworks at 74
plate showing windmill at 36
water supply of 74
windmills near 37–38, 65
Kettle Springs, nature of 24
Kirkwood, wells near 24
Knox County, well in 22
Lancaster County, wells in 20
Lincoln, plates and figure showing windmills near 38, 40, 44, 46, 64
salt wells at 76–77
water supply of 74–75
wells at and near 19, 20
windmills at and near 40–41, 46, 66
Lincoln County, blowing wells in 82
well in 22
Lena, well at 22
Logan County, well in 22
Loup County, well in 22
Loup River Valley, windmills in 35
Loveland, G. A., and Swezey, G. D., cited . 71, 72, 79
Macon, blowing well near 82
Madison County, well in 22
Madrid, well near 22
Mathiesen, Fred, windmill of 57
McComb, W. F., windmill of 64
McCook, experiment station at 25
well at 23
McPherson County, wells in 22
Merry-go-round windmills, construction of. 46–47
features of 44–48
figures showing construction of 45, 46
Milford, plate showing dam at 28
plate showing windmill near 66
windmill at 66
Moisture, conservation of 24–26
Moulton Ice Company, windmill of 66
Mound Springs, nature of 24
Mullen, well at 21
Nance County, well in 22
Nebraska, rainfall in 45
Nemaha County, well in 22
Newell, F. H., letter of transmittal by 11–12
Newport, windmill at 64
Norfolk, well near 22
North Platte, distribution of rainfall at 72
figure showing tympanum at 67
windmill at 66–67
Oberlin, Kans., experiment station at 25
O'Brien, J. F., cited 82
Ogallala, plate showing windmill at 60
windmills at 64–65
Olson, M. J., windmill of 59
Omaha, distribution of rainfall at 72
plate showing well at 18
salt well at 76, 77
water supply of 74
wells at and near 19, 20, 23
Ord, well near 21
Otoe County, wells in 22–23
Overton, plates showing windmills near ... 48, 58
windmill at and near 38–39, 49–50, 60–62
Oxford, experiment station at 25
Paddle wheels, features of 35–44
Palmyra, well at 23
Pardee, Lewis, windmill of 64
Pawnee, well near 22
Pawnee County, wells in 22
Peckham, E. L., windmill of 51–53
Peckham, J. S., windmill of 51–53
Perkins County, blowing well in 79
well in 22
Phelps County, blowing wells in 82
Pilger, well near 23
Platte County, blowing well in 82
well in 22
Platte River, irrigation from 27–28
plate showing 28
Platte Valley, windmills in 35, 47–50, 55
Pollution of water 26–27
Polk County, well in 22
Ponca, wells near 21
Portal, plate showing windmill near 54
windmill near 55–56
Precipitation in Nebraska, amount of 71–72
figure showing 71
Prinz, August, windmill of 54–55
Pumps, disadvantages of 44
Putney, S. Dak., deep plowing at 26

Page.
ı Nebraska, amount of 71-72
r County, well in 23
n Valley, windmills in 35
ells, features of 78-82
ıty, wells in 19, 23, 24
h, C. W., well of 81
ı, Kans., experiment station at ... 25
ıty, well in 23
ls, windmill at 57-58
:, salt marsh on 75-76
, location of 75-78
County, blowing well in 81
ıff County, well in 23
ıbo windmills, features of 41-42
ater, utilization of 27-28, 46
ıunty, artesian wells in 18
ı 23
ing, importance of 32
er, nature of 17-18
ll near 21
braska, character of 16-17
ounty, well in 23
well at 22
power, methods of 69-71
'. P., cited 73
g, well at 22
d, current wheel near 69
ear 22
. D., and Loveland, G. A., cited. 71-72, 79
John, windmill of 41
ll at 22
well in 20
er supply, use of windmill for 65-66
ion of power, figure showing
thod of 70
ds of 69-71
os., windmills of 40-41
vindmill at 41

Page.
Turbine windmills, features of 47
figures showing construction of. 58, 59, 60, 61, 62, 63
kinds of 47
reconstruction of 64-65
uses for 66-67
Tympanum water wheel, figure showing ... 67
novel uses of 66-67
Unadilla, well near 22
Underground water, action of 14-28
Union, mineral well at 77
University of Nebraska, plate showing windmill at 30
Valley County, well in 23
Videtto, S. S., windmill of 46
Warner, J. M., windmill of 60-62
Washington County, wells in 23
Water, height of 28
Water lifters, forms of 29, 67-69
Water supply for towns 73-75
Water table, height of 14-15
Weather wells, features of 78-82
Weeping Water, well at 21
Wheeler, Kans., experiment station at 25
Wheeler County, well in 23
Whitney, Milton, analyses by 16
Wilson, Matthew, windmills of 49-50
Windlasses, use of 29
Windmills, reconstruction of 64-65
uses of 29-31, 65-67
See Homemade windmills.
Winn, William A., windmill of 45
Wisner, well at 21
Woodlake, well at 21
Woulf, Fred, windmill of 50
York, wells at 23
York County, wells in 23

55TH CONGRESS, 3d Session. } HOUSE OF REPRESENTATIVES. { DOCUMENT No. 300.

DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 30

WATER RESOURCES OF THE LOWER PENINSULA OF MICHIGAN.—LANE

WASHINGTON
GOVERNMENT PRINTING OFFICE
1899

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR.

WATER RESOURCES

OF THE

LOWER PENINSULA OF MICHIGAN

BY

ALFRED C. LANE

WASHINGTON

GOVERNMENT PRINTING OFFICE

1899

CONTENTS.

	Page.
r of transmittal	9
ous uses of water	11
Jses where quantity is important	12
Transportation on the Great Lakes	12
Navigation on the smaller lakes and rivers	13
Log driving	13
City uses	14
Jses where head is important	17
Water powers in Michigan	18
Report on the run-off and water power of Kalamazoo River, by Robert E. Horton	22
Geology and topography	22
Rainfall and meteorology	26
Relation of lake level to rainfall	29
Run-off, rainfall, and water power	30
High water at Kalamazoo	35
Water power	37
Water power of Huron River	38
Developed power	39
Undeveloped power	41
Water power of Raisin River	41
Jses where quality is important	41
Drinking	41
Inorganic impurities	41
Organic impurities	42
Dairy use	43
Cooking, laundry, boilers	44
Sugar-beet industry	46
Photography and other uses	46
Quality and quantity compared	47
ate	48
Long-period variations in rainfall	54
Short-period fluctuations in water level	55
Well temperatures	56
rficial geology and topography	57
General description	57
Lakes of Lower Michigan	64
Wells in the Pleistocene	67
Methods of sinking wells	69
Eastern shore district	70
Saginaw Valley district	71
Northeastern shore district	73
Western shore district	75
North central district	76

P

Superficial geology and topography—Continued.
Saginaw moraine district
South central district
Deeper wells and Paleozoic stratigraphy
Carboniferous formation
Jackson coal measures to Marshall sandstone
Carboniferous and Devonian shales
Lower Marshall sandstone
Coldwater shales
Berea shale and grit
St. Clair black shales
Lower Devonian and Upper Silurian limestones
Traverse series (Hamilton)
Dundee limestone (Upper Helderberg)
Monroe and Salina beds (Lower Helderberg)
Niagara and Clinton formations
Hudson River and Utica shales
Trenton limestone
Rock structure and topography
Prospects of rock wells
Northern limestone district
Northern shale district
Coal basin
Southern shale district
Southeastern limestone district
Acknowledgments
Index

ILLUSTRATIONS.

		Page
LATE I.	Topographic map of Lower Michigan	16
II.	Map of the Pleistocene deposits	46
III.	*A*, Clinton boring apparatus; *B*, Field of onions in drained-lake bottom	54
IV.	Dutch Point sand spit, Grand Traverse Bay	66
V.	Barrier Beach connecting Empire Bluffs and Sleeping Bear Point, Lake Michigan	76
VI.	Geologic map of Lower Michigan, indicating also the topography of the rock surface	78
VII.	Index map of towns, indicating those where there are flowing wells and waterworks	90
G. 1.	Fluctuations in the level of Lake Michigan and the annual precipitation at Kalamazoo, Michigan	28
2.	Distribution of average minimum temperature in Michigan	50
3.	Distribution of average maximum temperature in Michigan	51
4.	Distribution of average mean temperature in Michigan	52
5.	Distribution of average annual precipitation in Michigan	53
6.	Sketch map of the drainage of Lower Michigan	61
7.	Diagram illustrating methods of stream capture	63
8.	Profile near Rose City, Michigan	68
9.	Diagram illustrating evils of insufficient casing	72
10.	Cross section of the Lower Michigan Basin	79
11.	Section of well at Midland, Michigan	82
12.	Geological column of Huron County, Michigan	85
13.	Section of well at Charlevoix, Michigan	87
14.	Map showing areas of shallow saline waters in Michigan	93

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, April 14, 1899.

R: I have the honor to transmit herewith a manuscript on the ter Resources of the Lower Peninsula of Michigan, by Dr. Alfred ane, and to recommend that it be printed as one of the series of er-Supply and Irrigation Papers. This material is a portion of the ome of Dr. Lane's studies in connection with the geological sur- of the State of Michigan, supplemented by statements received in y to circulars sent throughout the Lower Peninsula of Michigan ell drillers and others likely to be well informed and interested e subject. The facts thus gathered have been collated with the lt of two months' field work during the autumn of 1897. The plete report has assumed such bulk that it has been found neces- to divide it into several parts. The first of these, containing general conclusions, is herewith presented. The remaining data naturally into two classes, the first consisting of analyses of rs and the second of detailed descriptions of the supply at vari- localities visited. It is hoped that these data may be printed as eeding papers of this series.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

on. CHARLES D. WALCOTT,
Director United States Geological Survey.

'ATER RESOURCES OF THE LOWER PENINSULA OF MICHIGAN.

By ALFRED C. LANE.

VARIOUS USES OF WATER.

The region under consideration is generously endowed with water ıpplies, but it is apparent from experience elsewhere that these may › wasted or seriously depreciated in value by carelessness or lack of ıowledge of their extent and limitations. It is a common error to ıppose that if the limit to the supply of anything is not clearly in ght that the supply is inexhaustible; for example, the "practically exhaustible" supplies of pine of the Saginaw Valley of thirty years ;o are now nearly gone, and instances are cited of the sale of privi- ges of cutting the stumps on land already cut over for sums greater an the tracts originally cost. "Inexhaustible supplies" of natural ·s have failed; and, in short, it may be said that there is hardly a ıtural resource whose quantity or quality has not seriously deterio- ted through lavish use.

In many parts of the United States formerly as well watered as ichigan there has been apparently a shrinkage of water supply. he streams which at one time carried considerable volumes of water roughout the year are now reported to be, during summer at least, ›arly dry. Flowing wells have failed in many regions, either from ·ulty construction or from the multiplication of deep borings. In 'der, therefore, that it may be possible not only to utilize the water ·sources of the area under discussion to the fullest possible extent, ıt also to guard against causes of failure, it is desirable to bring ·gether all of the information available, combining the facts and ·awing broad conclusions.

Although the uses of water are almost infinitely varied, yet all kinds f water are not equally available for all purposes. The wide range ı the quantity of water and in its quality leads to an equal diversity ı application; for example, Michigan, as a whole, being humid, water as little value for agriculture, irrigation being practically confined · the use of water from city supplies applied to lawns, flower beds, ıd rarely to fruit trees and market gardens. On the other hand,

although water is so abundant consideration must be paid to its quality; that is, to the amount and kind of organic or inorganic matter held in solution or suspension. Another matter of primary importance is the elevation of the water with reference to possible fall, or, in other words, the head available. Upon this latter feature depends whether it can be used as a source of power or whether power must be consumed in raising it.

For certain uses practically the only thing desired is abundance of supply; for example, such city uses as fire protection, flushing sewers, and cleaning streets. The head required is generally obtained artificially. Only in exceptionally favored localities, such, for example, as those close to the edge of the moraine country on the lakeward side, is there head sufficient to obviate the use of pumps. This is the case in Hart, T. 15 N., R. 17 W.; Rochester, T. 3 N., R. 11 E.; and Rose, T. 24 N., R. 3 E.

There are other uses, however, in which quality is the first consideration; as, for instance, cooking and drinking. Finally, as a source of power water must, of course, have head.

Thus the different sources of supply and the different uses have been classified, so that one may see at a glance the more important factors in a given use and the sources which best meet the requirements. The most difficult problems to solve, however, are those where many needs are to be met by one system; where, as in a supply for a city, it is frequently necessary that ample quantity for fire protection and those use should be combined with at least a good degree of organic purity for drinking purposes and, if possible, with sufficient purity from lime and inorganic salts to be available for laundry use and for boilers. Such cases require special consideration and often present very complex problems.

USES WHERE QUANTITY IS IMPORTANT.

TRANSPORTATION ON THE GREAT LAKES.

The great extent of shore line and the use of the waters of the State for transportation require some notice, especially in their bearing on other water uses. Michigan is more cut up by the Great Lakes than any other State, having some 1,600 miles of shore line, and the commerce on the Lakes is growing at a remarkable rate. The commerce past Detroit is greater than that past any other port in the world The harbor master of Sand Beach estimates that a boat passes within sight every five minutes, day and night.

If commerce increases in the future as in the past, it may be doubtful whether the Great Lakes, and rivers like the St. Clair and Detroit, independent of the question of sewage emptied into them, will be sufficiently free from organic impurities to be available for city water supplies. At present the Great Lakes are the source of the water supply of most of the cities and towns on their shores.

NAVIGATION ON THE SMALLER LAKES AND RIVERS.

On many of the larger inland lakes, in which Michigan is so rich, and on some rivers tugs have been employed, mainly for pleasure or for towing logs. The lower parts of the rivers are used for harbors. Along the west shore, as at Manistee, Ludington, and Frankfort, the lower reaches of all the rivers are practically lakes. These lakes are separated from Lake Michigan by sand bars, which often have to be cut, after which the lakes make good small harbors. In this way Charlevoix Harbor has been connected with Pine Lake by a short cut, and Cheboygan is located on a river the mouth of which serves as a harbor. In the part of the State lying between Traverse City and Cheboygan it has been possible, with some artificial aid, to establish an extensive system of inland navigation. It may be noted, too, that for a long distance from its mouth the Saginaw River and its various branches are practically at lake level. In fact the watershed between the Grand River and the Saginaw, near Ashley, is only about 87 feet above the lake level, so that if, as has been suggested, a canal were to be built to cut off the long northern voyage by the Straits of Mackinac from Chicago and Milwaukee, it would be far easier to construct it along this line than any other. On the Michigan side Grand River is navigable nearly to Grand Rapids. Besides Saginaw River up to St. Charles, the mouths of Black River at Port Huron, of Thunder Bay River at Alpena, and of Huron River are used for short distances. Transportation by boat has, however, been checked along Saginaw River and other streams by their extensive use for the transportation of logs, to say nothing of the fact that they are very crooked.

LOG DRIVING.

A glance at the map will show that the branches of the Saginaw diverge in every direction, from north-northeast to east-northeast, and they have served to transport the pines to Saginaw and Bay City. For miles along their course the rivers have been packed solid with logs. Lumbermen's dams have been constructed along the headwaters, their object being to accentuate and regulate the floods. The Saginaw Valley has now, however, been converted into farming country, and Saginaw has its city water supply—which, fortunately, is not much used for drinking—from these rivers. In considering the use of the Saginaw and its branches for such purposes the fact must not be forgotten that for a large part of the year they are stagnant water, with the current setting up and down with the changes in the wind and in the level of the bay, and that they are lined with rotting logs. It is no wonder that the analyses of such streams show much organic matter. There are all along the shores of the peninsula, at the mouths of the more important streams, towns of considerable size which obtained their start as sawmill towns and which are, or were, supported

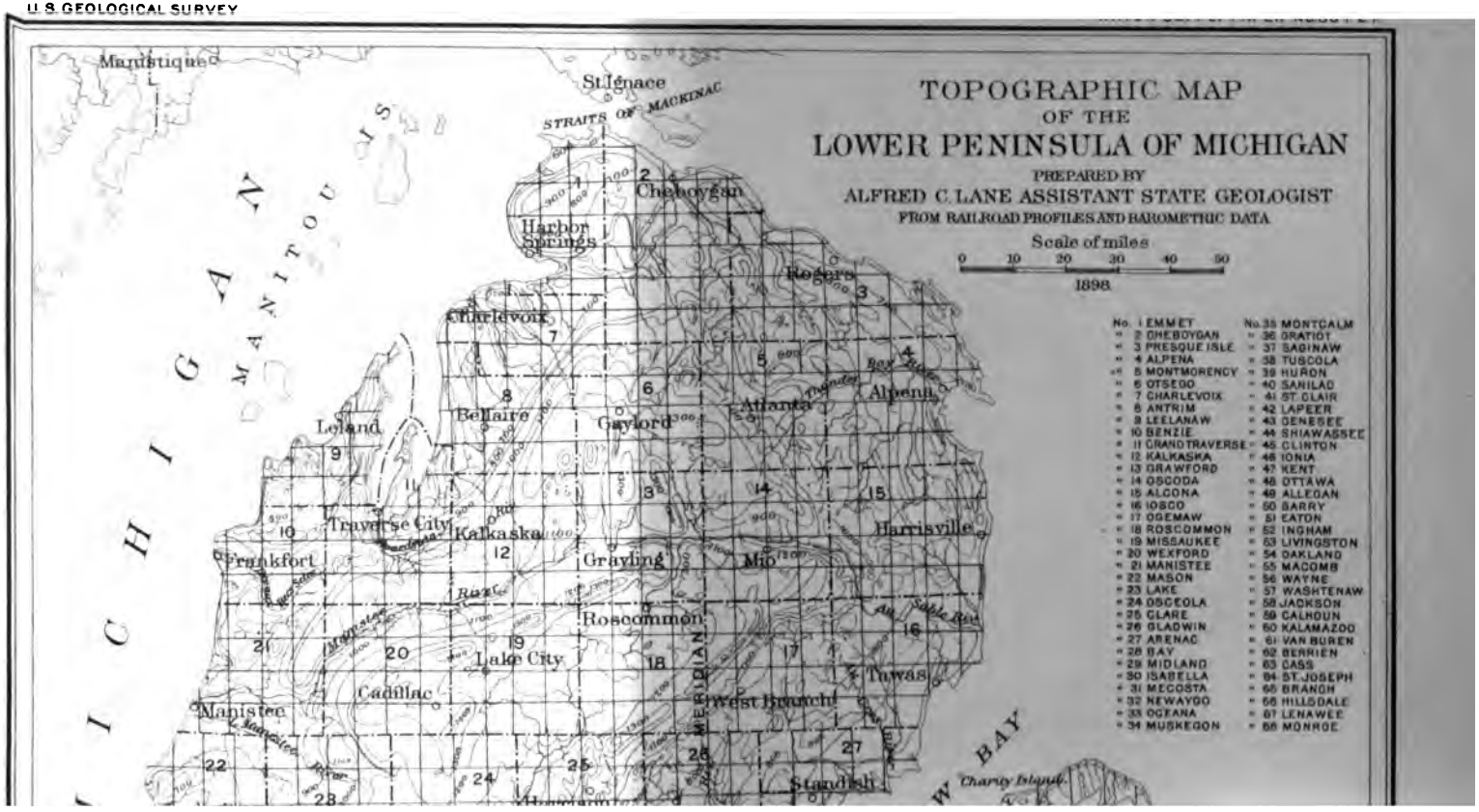
the need of quantity has too often been considered alone, and even the most rudimentary precautions for purity have been neglected.

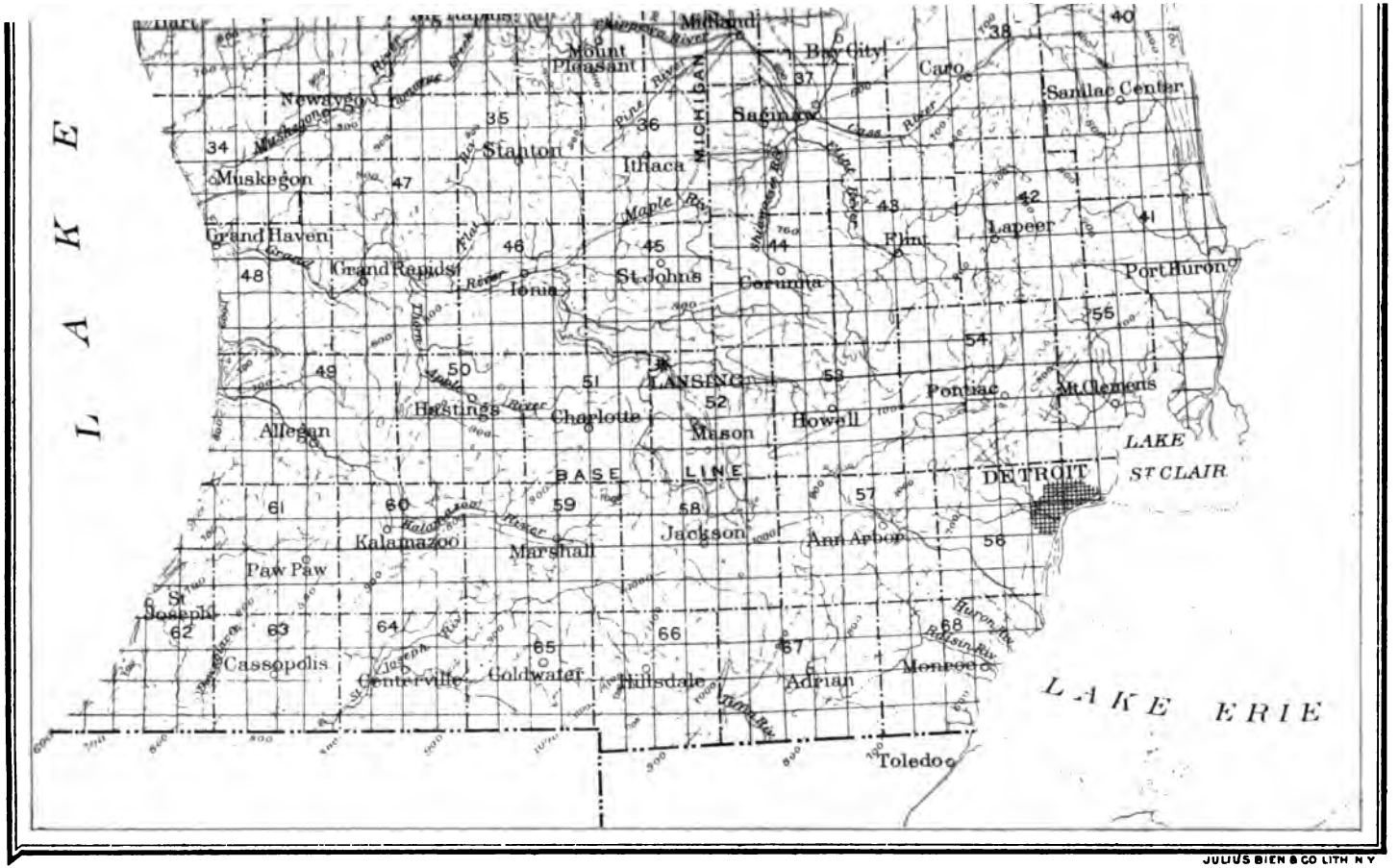
West Saginaw takes its water direct from the river, under a dock close to the heart of the city and near a large sewer, the settling tank being 75 by 22 feet and the river current variable. The water is of a muddy-green color, with a good deal of bark floating around in the tank. Alma takes water from a mill race 300 feet above a sewer. There is no protection to the banks of the stream above. Both of these places, however, use almost exclusively for drinking purposes water from deep wells which comes under clay and is therefore safe. In Saginaw it is said that the salt water from the deeper wells has found its way into some of the shallower rock wells and contaminated them, and the waste bitterns go into the river. But individual wells, however numerous, are not an ideal supply for a large town, with the running here and there to neighbors, the possibility of some wells being too shallow to be safe, and the liability to contamination from dug wells. The Saginaw is so sluggish a stream that it is practically a pond. A plant situated as far up as the East Saginaw plant, therefore, if the banks were bought for a "riverside park" and protected for a few miles, and if the reflux of water from the lower river were prevented, especially if there were a gravel bed instead of decaying planks between the settling tank and the river, might furnish a fairly satisfactory water supply; but one would probably not have to go far—not beyond Vassar—to secure an ample and pure supply in sandstone. Analyses of these waters will be given in a later paper. Most of the other large cities are supplied from the Great Lakes, and seem to find no objection to that source, though Chicago's experience shows that there is a possibility of danger to be guarded against.

Many towns, however, like Rochester, Birmingham, Hunt, Petoskey, Charlevoix, Harbor Springs, Bay View, and Cheboygan have found a sufficient supply in deep wells, and most towns of the State could be thus supplied if they were willing to give up the use for garden hose, motors, etc. The construction of a large reservoir to meet the extra heavy demand of summer might be feasible. One practicable way would be to limit the use of garden hose to a short time each day, during which time the reservoir or some inferior filtered source of supply could be drawn upon. It is an advantage of this plan that the efficacy of a gravel filter bed is immensely increased if it is not continuously in use.

The use of water in our Michigan towns is extravagant, and the difficulty of securing a proper quality is correspondingly increased. For example, Bay City, with a population of about 33,000, besides the supply from wells, in 1896 used 197 gallons a day, about 5 per cent of which was through manufacturing meters, 5 per cent through domestic meters, and the rest at fixed rates. The special water supply committee of the city council of Traverse City, 1897, George W.

1


TOPOGRAPHIC MAP
OF THE
LOWER PENINSULA OF MICHIGAN
PREPARED BY
ALFRED C. LANE ASSISTANT STATE GEOLOGIST
FROM RAILROAD PROFILES AND BAROMETRIC DATA
Scale of miles
0 10 20 30 40 50
1898
No. 1 EMMET
" 2 CHEBOYGAN
" 3 PRESQUE ISLE
" 4 ALPENA
" 5 MONTMORENCY
" 6 OTSEGO
" 7 CHARLEVOIX
" 8 ANTRIM
" 9 LEELANAW
" 10 BENZIE
" 11 GRAND TRAVERSE
" 12 KALKASKA
" 13 CRAWFORD
" 14 OSCODA
" 15 ALCONA
" 16 IOSCO
" 17 OGEMAW
" 18 ROSCOMMON
" 19 MISSAUKEE
" 20 WEXFORD
" 21 MANISTEE
" 22 MASON
" 23 LAKE
" 24 OSCEOLA
" 25 CLARE
" 26 GLADWIN
" 27 ARENAC
" 28 BAY
" 29 MIDLAND
" 30 ISABELLA
" 31 MECOSTA
" 32 NEWAYGO
" 33 OCEANA
" 34 MUSKEGON
No. 35 MONTCALM
" 36 GRATIOT
" 37 SAGINAW
" 38 TUSCOLA
" 39 HURON
" 40 SANILAC
" 41 ST. CLAIR
" 42 LAPEER
" 43 GENESEE
" 44 SHIAWASSEE
" 45 CLINTON
" 46 IONIA
" 47 KENT
" 48 OTTAWA
" 49 ALLEGAN
" 50 BARRY
" 51 EATON
" 52 INGHAM
" 53 LIVINGSTON
" 54 OAKLAND
" 55 MACOMB
" 56 WAYNE
" 57 WASHTENAW
" 58 JACKSON
" 59 CALHOUN
" 60 KALAMAZOO
" 61 VAN BUREN
" 62 BERRIEN
" 63 CASS
" 64 ST. JOSEPH
" 65 BRANCH
" 66 HILLSDALE
" 67 LENAWEE
" 68 MONROE
Manistique
St. Ignace
STRAITS OF MACKINAC
Cheboygan
Harbor Springs
Rogers
Charlevoix
Alpena
Atlanta
Bellaire
Gaylord
Leland
Traverse City
Kalkaska
Harrisville
Frankfort
Grayling
Mio
Roscommon
Lake City
Cadillac
Tawas
Manistee
West Branch
Standish
Charity Island
MANITOU IS.
MICHIGAN
SAGINAW BAY



JULIUS BIEN & CO LITH N Y

Rafter, consulting engineer, figured upon supplying 100 gallons a day to a population three times the present. This is one of the most carefully studied of recent propositions and the report compares a number of typical city sources of supply.

USES WHERE HEAD IS IMPORTANT.

The use of water for motive power depends not only on the quantity, but also on the head. The total energy is expressed by the product of these two. There are two widely different conditions under which water is thus used. The one is where the head is first artificially obtained and the water is raised by pumping. In such cases the water acts merely as a distributor of power. In this way water is used in many of the cities and towns, running motors for light machinery, especially for elevators. The chief advantages are that it is ready at hand, quiet, noiseless, odorless, not dangerous, and convenient in every way. There is, however, considerable loss of head in narrow and crooked pipes, and it is not the most economical method of transmitting power, while the extra quantity of water needed makes the attainment of desirable quality far more difficult. Electricity may be expected to relieve our water systems of much of this burden of power transmission. The other use is where natural water power is utilized. In respect to natural water power, Michigan is much better situated than many adjacent States, though there are no very large streams except the international Detroit and St. Clair rivers, which are not dammed.

A large area, both in the northern and southern part of the State, is more than 1,000 feet above tide, or say 400 feet above lake level. It will be noticed, too, from the contour map (Pl. I) and from fig. 10 that the descent from the 1,000 to the 700-foot contour line is frequently quite rapid, and here is a great belt of water powers.

In a few cases, as at Traverse City and around West Branch, flowing wells furnish such a volume of water as to be of considerable power. Around West Branch and Rose City such wells distribute water into the second stories of the houses, and at Traverse City, as at Harbor Springs, it has been proposed to use part of the water in a hydraulic ram to elevate the remainder.

But the head of flowing wells is of most importance in saving the power, windmill or steam, which would otherwise be required to elevate the water.

There are also many lakes—and these chiefly in the highest parts of the State—which help to steady the flow of the streams by acting as reservoirs, though many of them are quite variable in their water stage. For instance, Clam Lake, near Cadillac, is said to have varied more than 16 feet. Thus conditions are quite favorable to the development of water power in streams, and small water powers, suited for village waterworks, electric-light plants, country sawmills

and gristmills, etc., are widely distributed along the edge of and in the morainal areas. Almost uniformly wherever, as explained later (p. 63), the earlier high-level Glacial drainage has been captured and diverted by streams which have worked back across the moraines, good sites for water powers may be found, though thus far the abundance of fuel and the relatively heavy first cost of waterworks improvements have retarded their development somewhat.

WATER POWERS IN MICHIGAN.

The following table of places where water powers have been observed or reported is doubtless very incomplete. More complete accounts are given of the two important regions which have been studied in greater detail. The southeastern part has been studied in connection with the Tenth Census, and Kalamazoo River has been studied by Mr. Robert E. Horton. It must not by any means be inferred that the Huron and the Kalamazoo are, from the importance given to them, the most important water-power streams of the State. They are merely those of which the most is known, and the study of the Grand River system, and others equally important in the northern part of the State, would require more time and money than have been allotted to this paper.

Water powers in Michigan.

Stream.	Location of power.	Remarks.
LAKE ERIE DRAINAGE.		
Raisin River	Few above Adrian	
Huron River	Dexter to Ypsilanti, mainly.	See Report on Water Powers, Tenth Census. See also Winchell, Geology of Washtenaw County, 1881, p. 19.
Do	Ypsilanti (5-foot fall)	Water power for waterworks pumping station.
Do		Grist mill. About 10-foot fall.
Do		Underwear factory.
Do	Pettibone mills, Milford	Paper mill.
Tiffin River	Below Hudson	Small.
DETROIT RIVER DRAINAGE.		
River Rouge (Ecorce River).	Northville	Above Plymouth; small flow, considerable fall.
LAKE ST. CLAIR DRAINAGE.		
Clinton River	Rochester	Above Utica are numerous small powers.

Water powers in Michigan—Continued.

ST. CLAIR RIVER DRAINAGE.

Stream.	Location of power.	Remarks.
Belle River		
Mill Creek	Below Yale	
Black River		Poor power; a stream of diminishing drainage area; swamps being cleared and summer drought becoming accentuated.
THUMB OF MICHIGAN.		
Allen Creek	Rock Falls	10-foot head; not much water; abandoned.
Willow River	Huron	Abandoned.
Pinnebog River	Near Popple	Not used; drainage area growing, but the swamps are being cleared.
Pigeon River	Above Wolfton	Not used.
SAGINAW RIVER DRAINAGE.		
Cass River		A stream of diminishing drainage and sandy course.
Do	Caro	Undeveloped.
Do	Vassar	4-foot fall.
Flint River	Flint to Columbiaville	Good power near Flint.
Shiawassee River	Owosso	
Do	Corunna	10-foot fall.
Pine River	St. Louis and Alma, up to Millbrook.	At St. Louis dam; at Alma a dam with 10-foot head helps run elevator and waterworks.
Chippewa River	Mount Pleasant	15-foot fall runs waterworks, electric-light plant, and elevator.
Do	Barryton	Dam; 8-foot fall.
Salt River		
Tobacco River	Farwell and Clare	
Tittabawassee River		Very sandy and sluggish, except at head waters.

Water powers in Michigan—Continued.

LAKE HURON DRAINAGE NORTH OF SAGINAW RIVER.

Stream.	Location of power.	Remarks.
Rifle River		Good mill stream.
Houghton Creek	Rose City	10-foot dam.
Au Gres River		Small stream, with considerable valleys and fall where crossing the 200-foot contour line.
Au Sable River	Especially through the stretch from Mio to T. 24 N., R. 6 E.	Splendid water powers; unused, largely fed by springs, with a comparatively small flood plain.
Do	Grayling	Dam.
Thunder Bay River	Alpena. Numerous	Brodwell's mills and Trowbridge's mills.
Cheboygan River	Long Rapids to Hillman.	Little fall.
Oqueoc River		
Sturgeon River	Sec. 3, T. 34 N., R. 1 E.	Mill.
Rainy River		Probably some powers; rock banks.
Pigeon River		
Mulletts River	Wolverine to Trowbridge.	

LAKE MICHIGAN DRAINAGE.

Bear River	Petoskey	Ingalls mills.
Boyne River	Boyne Falls	Other similar small streams to southwest.
Elk River	Elk Rapids	Wing dam and undershot wheel; put in as early as 1850; note the very large lake drainage; steady power.
Duck Lake	Outlet	9-foot fall; 60–70 horsepower used.
Boardman River		Variable; near Traverse City 20-foot head; flow in drought about 100 cubic feet a second. See p. 31.
Carp River		Outlet of Carp Lake; 5 to 6 foot fall.
Betsie River	Weldon Township	
Do	Benzonia	

Water powers in Michigan—Continued.

LAKE MICHIGAN DRAINAGE—Continued.

Stream.	Location of power.	Remarks.
Crystal Creek	Outlet of Glen Lake	2 or 3 powers.
Manistee River	Lower part	Sandy valley; drainage area diminishing; numerous small mill sites; quite variable.
South Branch		Rapid fall below Tustin.
Little Manistee River		
Big Sable River		
Notepseakan River		
White River		
Muskegon River	Newaygo	
Do	Big Rapids	30-foot fall; large stream; steadied inflow by lakes and springs; furniture factories, etc.
Crockery Creek		
Rabbit River		
Kalamazoo River		See report by Robert E. Horton, pp. 22–38.
Coldwater River		
Hog Creek		
Fawn River	Near Burrows	
Grand River	Grand Rapids	Large manufacturing power.
Flat River	Fallassburg	35-foot fall between here and at Lowell.
Rouge River		
Bear Creek	Cannon, T. 8 N., R. 10 W	200-foot fall in 12 miles.
Apple Creek	Caledonia, T. 5 N., R. 10 W.	
Do	Alpine, T. 8 N., R. 12 W	Tributaries of Grand River; mill sites in eastern part.
Thornapple River	Cascade, T. 6 N., R. 10 W	Fine water power.
Do	Whitneyville	
Cedar Creek		Good mill stream.
Do	Ada	Two mills.
Buck Creek		Mill stream.
Grand River	Grand Ledge	Factories. There are numerous small powers among the headwaters of the Grand.
Do	North Lansing	9-foot fall. Also a dam at South Lansing.
Do	Eaton Rapids	

Water powers in Michigan—Continued.

LAKE MICHIGAN DRAINAGE—Continued.

Stream.	Location of power.	Remarks.
Grand River	Jackson	Dams; about 10-foot head.
Paw Paw River	Almena, T. 2 S., R 13 W	Spring Brook, one of the headwaters, has 18-foot head running a saw and feed mill, about 821 cubic feet a day; lowers 5 or 6 inches a day, but fills up over night. The brook starts in a big spring 1 mile away and passes through two lakes. Adjacent brooks furnish similar powers of local value.

REPORT ON THE RUN-OFF AND WATER POWER OF KALAMAZOO RIVER.

By Robert E. Horton.

GEOLOGY AND TOPOGRAPHY.

The Kalamazoo River rises in the south central part of the Lower Peninsula of Michigan and flows in a northwesterly direction, debouching into Lake Michigan 3¼ miles below the village of Saugatuck. Its current is slow, averaging about 3 miles an hour, and its slope uniform, there being no waterfalls and no considerable rapids except at two points, at each of which there occurs a descent of 3 or 4 feet within a distance of a few rods. The river flows through a rich agricultural region, in a valley from one-fourth of a mile to 2 or 3 miles in width, backed by low hills or sloping gently to the upland. The flat lands in the valley are often flooded and serve largely as permanent meadows through which the river winds, often in a very tortuous manner. Two branches unite at Albion to form the main stream. The total length from the point of juncture to the outlet is 101 miles.

In respect to the climate, topography, and run-off of its watershed Kalamazoo River may be considered as typical of the larger streams of southern Michigan, including the Grand, the St. Joseph, and the Raisin, all of which find their sources within a few miles of each other and of the Kalamazoo. The drainage area covers 1,750 square miles overlaid with Pleistocene deposits. The surface formations are distributed about as follows: Morainal ridge and glacial drift covers between 25 and 45 per cent of the watershed; clay-loam till plains, 25

to 35 per cent; overwash valley train deposits of the ice drainage, 35 to 45 per cent. The latter lies chiefly in the middle and upper portions of the watershed, underlying short tributaries with swamp drainage. The clay-loam till plains form basins for lake storage, but give small flow from ground storage. The surface soil is diversified. Gravel, clay, and loam, mixed with sand, alternate in relatively small areas.[1]

Between Albion and Augusta, a distance of 34 miles, the main river channel lies between parallel morainal ridges deposited by the east wing of a reentrant cusp of the ice front which had at one time worked back step by step from the Indiana line. Between Kalamazoo and Plainwell the river channel cuts through the more northerly of these parallel ridges. The Valparaiso moraine and Covert ridge, running parallel to the above and to the lake front, are similarly crossed below Otsego.

The main river below Kalamazoo largely follows lines of pre-Glacial drainage. In the upper portion of the watershed the tributaries, which are numerous and ramify extensively, generally disregard the morainal contours in their courses, while the main stream follows them closely. There is a fall of from 12 to 20 feet, within a distance of about a mile, at the point of discharge of a number of tributaries, furnishing excellent water powers at points where the extent of the flats prevents dams being built on the main river.

The depths in feet, as determined from deep borings of the drift sand and shale deposits underlying the river channel at various points along its course, are as follows:[2]

Sections below channel of Kalamazoo River.

Place.	Distance from mouth of stream.	Depth of glacial drift.	Depth of sand rock.	Depth of blue shales below sand rock. *a*
	Miles.	*Feet.*	*Feet.*	*Feet.*
Albion	101	10	271	100
Marengo	93	60	200	200
Marshall	88.8	70	43	327
Battle Creek	75.5	70	43	320
Kalamazoo	52.1	130	(*b*)	(*b*)
Allegan	32.5	260	75	770

a As far as measured. *b* Together, 1,070 feet.

The line of the supposed outcrop of the bottom of the Marshall sandstone crosses the watershed in a northwesterly and southeasterly direction, intersecting the river channel below Battle Creek.

[1] See effect of drift upon topography and drainage, by Frank Leverett: Seventeenth Ann. Rept. U. S. Geol. Survey, Part II, pp. 706-711.

[2] The geology of Lower Michigan with reference to deep borings: Geol. Survey Michigan, Vol. V, Part II.

There are, within the catchment basin, a large number of small lakes and spring hollows, in which water stands part or all of the time. Many of these have no surface outlets and feed the stream only through seepage or ground flow, a large portion of their waters being consumed directly by evaporation. Each of these lakes drains an area varying generally from six to twelve times its own area, and their combined catchment reduces materially the area directly tributary to the river. The following table shows the relative number and area of tributary and nontributary lakes within the watershed in the four counties having the largest tributary drainage:[1]

Tributary and nontributary lakes in the watershed of Kalamazoo River.

County.	Drainage of river.	Number of tributary lakes over ¼ mile in diameter.	Area of tributary lakes.	Number of nontributary lakes within drainage area.	Area of nontributary lakes.
	Sq. miles.		*Sq. miles.*		*Sq. miles.*
Calhoun	486.63	58	3.69	47	2.95
Jackson	148.5	21	1.29	38	0.32
Kalamazoo	273.5	39	5.29	31	2.25
Allegan	637.	65	6.59	25	.64

It will be seen that most of the lakes are tributary. About 1½ per cent of the drainage area is lake surface. Probably 5 or 6 per cent drains into nontributary lakes.

The surface of the watershed is rolling. Prairie, swamp, and hilly stretches alternate at short intervals. Many lakes and a considerable area of swamp lands have been made to yield their waters directly to the stream through drainage.[2] To what extent the diminution of lake and swamp storage and of forested areas for the purposes of agriculture has been detrimental to the flow of the stream and to its value for water power can only be inferred. The oldest mill owners and water-power users strongly maintain that the river yields less power than formerly, holding that the flow is less uniform and the volume appreciably smaller than in pioneer days.

[1] These data have been obtained chiefly from atlases of the various counties.

[2] The problem of swamp drainage has been carefully studied. Peppermint and celery are largely grown on drained areas. See Michigan Engineer's Annual; Drainage engineering, by R. C. Carpenter: Proc. Michigan Engineering Society, 1882, pp. 40-48; Drainage of large marshes, by C. E. Hamilton: Proc. Mich. Eng. Soc., 1884, pp. 15-19; Reclamation of swamp lands, by O. H. Todd: Proc. Mich. Eng. Soc., 1894, pp. 57-66.

The distribution of cultivated, forest, meadow, and swamp areas in the watershed is as follows:[1]

Character of watershed of Kalamazoo River.

	Per cent.
Improved tilled land, including meadow and grass in rotation	60
Permanent meadows, pastures, orchards, etc	7
Woodland and forest	11
Undetermined, including waste swamp, lakes, building plats, villages, etc	22
Total	100

The character of the vegetation is an important factor in determining the proportion of rainfall on a watershed which reaches the stream as run-off during the summer months. The distribution of the principal crops grown and the number of inches of water they will require on the entire watershed during the growing season, are shown in the following table:

Distribution of crops in the watershed of Kalamazoo River.

Crop.	Entire watershed covered in 1896. *a*	Water required during growing season. *b*	Water required on the entire watershed.
	Per cent.	*Inches.*	*Inches.*
Wheat	11.2	10.8	1.2
Corn	8.0	13.3	1.1
Oats	4.0	16.6	0.7
Rye	3.3	9.1	0.3
Potatoes	0.7	4.6	0.03
Beans	1.7	4.6	0.08
Hay	6.9	20.5	1.4
Gardens, barley, millet, mint, etc	10.0	*c* 15.0	1.5

a From Farm Statistics of Michigan, 1896, issued by the secretary of state, Lansing, Michigan, 1896, may be taken as an ordinary year.

b After Risler's data. See Report of State Engineer and Surveyor of New York for 1894, pp. 373-377.

c Average.

The length of the growing season has been taken as one hundred days, including the months of June, July, and August, and part of September. The average date of the first heavy or killing frost varies in different localites of the watershed. The limiting dates will usually be between September 25 and October 10. The inches of water required on the entire watershed has been obtained by multiplying the depth required by each crop by the percentage of the whole area covered. Comparing these with the former data the following amounts are obtained as the water requirements of vegetation during the growing season of an ordinary year.

[1] Deduced from acreage data given in census of Michigan, 1894, Vol. II, Table I.

	Inches.
Leading crops on tilled area	6.6
Permanent meadows, etc	1.1
Woodland and forest, 11 per cent at 4 inches	0.4
Add for areas not otherwise included	3.0
Total depth required by vegetation	11.1

RAINFALL AND METEOROLOGY.

In order to obtain the true mean rainfall of the watershed it would be necessary to have long contemporaneous records at stations uniformly distributed throughout the region. Rainfall records have been maintained within the Kalamazoo watershed at the stations, and for periods shown in the following table. Column 5 gives the average yearly rainfall at the station multiplied by the percentage of the entire watershed, which it may be fairly said to represent. In this way the mean annual rainfall of the entire watershed is found to be 33.87 inches. Toward the mouth of the stream the depth of the annual rainfall increases several inches.

Rainfall on watershed of Kalamazoo River. (*a*)

1 Station (proceeding downstream).	2 Years.	3 Mean annual rain and melted snow.	4 Proportion of watershed represented by each station.	5 Rainfall on entire watershed for each station.	6 Probable annual fluctuation.*b*
		Inches.	*Per cent.*	*Inches.*	*Inches.*
Hanover	1886–1896	32.89	3.33	1.10	±4.2
Pulaski	1888–1891	28.54	4.16	1.19	3.8
Concord	1888–1892	29.39	5.56	1.63	2.8
Olivet	1888–1892, 1896	33.16	12.22	4.00	4.5
Marshall	1881–1892	35.70	6.39	2.28	2.0
North Marshall	1889–1896	30.28	3.75	1.14	4.3
Battle Creek	1876–1880, 1885, 1895, 1896.	29.18	11.22	3.35	4.4
Kalamazoo	1876–1896	36.45	20.40	7.42	4.0
Allegan	1890–1896	35.75	32.97	11.76	4.2

a The meteorological data used in this report have been supplied by Mr. C. F. Schneider, director Michigan weather service.

b Deduced from the records in accordance with the theory of probabilities by Peters's formula.

Inasmuch as the rainfall at a station for any year can not be less than the mean by an amount exceeding 100 per cent, but may be more than 200 per cent of the mean, one would expect to find slightly more dry years than wet years in a long rainfall record. Out of eighty yearly records used in the table, thirty-nine were above the station means and forty-one were below. The twenty-one year record at Kalamazoo showed twelve years below and nine years above the

mean The fluctuation from the mean for dry years, or, in other words, the severity of the drought, will be less than the average fluctuation from the mean for wet years, in proportion as the number of dry years is greater than the number of wet years. The variability or probable fluctuations of rainfall, in inches, for any single year above or below the mean is shown in column 6.

The best record of rainfall within the watershed is that at Kalamazoo, covering twenty-one years, from 1876 to 1896, inclusive. The distribution of the monthly rainfall and the temperature throughout the year at Kalamazoo are shown by the following table. The heaviest rainfall occurs in the months of May and June, but that in August is most variable. This is probably due to the prevalence of thunderstorms during that month, which is also a month of high mean temperature. January has the lowest mean temperature, the least precipitation, and the least variability.

Monthly rainfall and temperature at Kalamazoo.

Month.	1 Mean monthly rainfall and melted snow.	2 Proportion of the mean yearly rainfall.	3 Probable fluctuation above or below the mean for a single year.	4 Mean monthly temperature at Kalamazoo. a
	Inches.	*Per cent.*	*Inches.*	° *F.*
January	2.24	6.2	0.63	23.08
February	2.40	6.6	0.92	25.45
March	2.42	6.7	1.01	32.15
April	2.63	7.2	1.21	46.95
May	4.47	12.3	1.02	58.58
June	4.58	12.6	1.35	68.35
July	3.15	8.6	1.15	72.17
August	2.79	7.6	1.46	69.64
September	3.36	9.2	1.31	61.73
October	2.76	7.5	0.90	50.34
November	2.97	8.2	0.88	37.03
December	2.70	7.3	1.12	28.19
For the year	36.47	.....	4.03	47.9

a 1876 to 1895.

The data in the above table accord well with the observed character of the stream, which is usually about as follows: A spring freshet in March or April is followed by medium water until June. High water often occurs for a few days after heavy rains in June, and sometimes also in August. Low water in later July, August, and September is accompanied by a depletion of stored ground water. Gradual increase in the flow occurs until the ground becomes frozen. Winter flow is

uniform and moderate, unless the stream is swelled by sudden melting of snowfalls. This frequently occurs in January or February, and is followed by moderate high water until the spring thaws.

In so far as the meteorological records at the different stations within the watershed are contemporaneous, they show a tendency for like variations from the mean rainfall and temperature at all stations during the same year. The region may therefore be considered fairly isoclimatic, since changes affecting any large portion of the watershed will in general similarly affect the whole region.

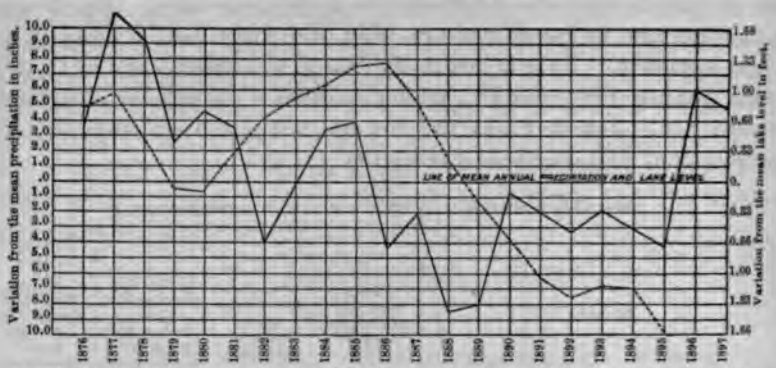


FIG. 1.—Fluctuations in the level of Lake Michigan and the annual precipitation at Kalamazoo, Michigan. (Prepared by R. E. Horton.)

The yearly rainfall record at Kalamazoo is shown by the solid line in the accompanying diagram (fig. 1). It will be seen that the yearly fluctuations from the mean annual rainfall are periodic in their occurrence. The ordinary cycle consists of a primary minimum followed by a period of increase for one to three years, and terminates in a primary maximum followed by a period of decrease for four or five years. This latter has a secondary superimposed cycle with its minimum and maximum usually one year apart. The times of recurrence of the different phases of the cycles thus far observed are shown in the following table:

Periodic rainfall at Kalamazoo.

Phase.	1	2	3	4
Primary minimum	.....	1882	1888	1895
Primary maximum	1877	1885	1890	1896
Secondary minimum	1879	1886	1892	.....
Secondary maximum	1888	1887	1893	.....
Whole period, years	6 or 7	6	7	.....

A fifth minimum may be expected about 1901.

Rainfall records at other stations within the watershed do not cover a sufficient number of years to determine whether there is a similar

periodicity in the rainfall throughout the watershed, nor are there gaging data at hand to show whether a corresponding periodic decadence takes place in the stream flow. If such should prove to be the case, the fact should be of commercial value to farmers and water-power users. The existence of a short rainfall cycle following such a regular periodic law is worthy of remark. Periodic fluctuations in rainfall having cycles of greater length than the above have been observed at various places in this country and abroad. At Sacramento, California, a forty-year rainfall record exists showing a six or seven year cycle as at Kalamazoo.[1] Many long records show no regularly recurring cycles, but in all cases which the writer has observed two or more successive dry or wet years occur with much greater frequency than would be the case if the sequence of wet or dry years were purely a matter of mathematical calculation. As a safe conclusion it may be said that certain meteorological conditions underlying rainfall tend to recur in more or less obscure cycles. It seems not improbable that the causes of such cycles are general in their application; and their apparent effects in many instances are masked by local or secondary conditions. The final solution of the problem will have an important bearing on questions relating to the water resources of any region.

RELATION OF LAKE LEVEL TO RAINFALL.

Observations of the height of the water surface of Lake Michigan have been made since 1800. In the absence of longer rainfall records within the watershed any relation that may be found to exist between the rainfall and the lake levels will be helpful in studying the run-off. The different kinds of fluctuations to which the water level of the lake surface is subject may be classified in relation to the causes producing them, as follows:

(1) Small tides, which at Chicago the United States Lake Survey found to have an amplitude of 1½ inches for neap tide to 3 inches for spring tide.

(2) "Seiches," so called, similar to those observed on Swiss lakes, and not thus far satisfactorily explained. They consist of small waves or pulsations having an interval of about ten minutes from impulse to impulse and apparently recurring without cessation.

(3) Temporary fluctuations, due to the wind. Colonel Whittlesey states that on August 18, 1848, a gale from the northeast reduced the water level at Buffalo 15½ feet lower than on October 18, 1894, the time of a terrible gale from the southwest.

(4) Annual variations, caused chiefly by differences of temperature and evaporation and by the melting of snow and ice. On Lake Michigan low water usually occurs in November and March. The highest water occurs in June and July.

[1] See climate, soil, characteristics and irrigation methods in California, by Charles W. Irish: Yearbook U. S. Dept. Agric., 1895.

(5) Secular variations, covering periods of several years, dependent n rainfall and meteorological conditions. The length of the periods s irregular and the times of recurrence of maximum and minimum hases can not be predicted closely. Knowing the mean annual levels or a series of years we may expect a similar series in the future, but vith the times of the different phases very different. The number of naxima and minima within a given interval of years will, however, e nearly uniform for long series.[1]

On the accompanying diagram (fig. 1) the height, in feet, of the vater surface of Lake Michigan, above or below the mean level (viz., 81 feet above tide) is shown, by a broken line, for a period of twenty-ne years, 1876 to 1896, inclusive. It will be noticed that the lake evels are subject to a much greater relative fluctuation than is the ainfall. The two curves follow each other somewhat closely, although he periods are longer and more continuous for the lake levels. The 'ear 1896 is exceptional in that it shows the lowest lake level recorded, vhile it was the year having the highest recorded rainfall at all stations vithin the watershed except Kalamazoo, where it was third in rank for wenty-one years. There is reason to believe that the level of Lake Iichigan and the rainfall and the run-off of the watershed are covari-nts. Exceptional years can be ascribed to high summer temperature, roducing luxuriant vegetation and excessive evaporation, so that lit-le rainfall appears as run-off, or else the distribution of the rainfall hrough the year may be unfavorable to its reaching the streams and ake as run-off. The former was apparently the case in 1896. Care-ful inquiry from power users showed that within the Kalamazoo watershed there was a much greater shortage of water in the river in 1896 than in 1897, a year of considerably lower rainfall and mean temperature during the summer months. The mean rainfall at six stations in the watershed in 1896 was 41.9 inches, or 8 inches above the average.

RUN-OFF, RAINFALL, AND WATER POWER.

In studying stream flow it should be borne in mind that the amount of rainfall appearing as run-off in a given year is the resultant of a large number of more or less independent influences. Conditions may so combine that those factors which would ordinarily be in the background will in some instances become the controlling elements. Few, if any, rules without exceptions can be laid down, and each stream must be studied separately in all its relations.

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[1] The following references have been consulted in relation to lake levels:

(*a*) Chart of Fluctuations in the Level of the Great Lakes, by Charles Crosman, Milwaukee, Wisconsin.

(*b*) Climate of the Lake region, by Bela Hubbard: Pop. Sci. Monthly, January, 1888.

(*c*) Water-supply of western division of Erie Canal, by George W. Rafter: Report State Engineer and Surveyor of New York, 1896.

(*d*) Report United States Deep Waterways Commission: Washington, 1896.

(*e*) Reports of Chief of Engineers, U. S. Army.

'he following table shows the discharge of the Kalamazoo water-
ɔd corresponding to different percentages of the mean annual rain-
l appearing as run-off in the stream:

Relation between run-off and discharge of Kalamazoo River.

Proportion of mean annual rainfall appearing as run-off.	Depth of run-off on entire watershed.	Mean discharge of the stream.
Per cent.	*Inches.*	*Second-feet.*
110	37.26	4,803.2
100	33.87	4,366.5
90	30.48	3,929.8
80	27.09	3,493.1
70	23.7	3,056.5
60	20.31	2,619.9
50	16.92	2,183.3
40	12.53	1,646.7

'he discharge of the Kalamazoo River was measured at a number
points along the stream during the spring high water of March, 1898.

Discharge of the Kalamazoo River at the Marengo dam, March 23, 1898.

w over dam and wasteweir	second-feet	456.8
arted for power purposes	do	113.
Total discharge	do	569.8
inage area above dam	square miles	261.
:harge per square mile	second-feet	2.18

'he depth of water flowing over the crest of the dam on March 23
ı 15 inches. The height for maximum flow, which occurred on
rch 22 and lasted only a few hours, was 24 inches. This would
'e corresponded to a total discharge of about 930 cubic feet per
ɔnd, or 3.5 cubic feet per second per square mile of drainage. We
y compare this flow with that of Boardman River at Traverse
y, a stream having a drainage area of 295 square miles. The river
ı measured on April 10, 1897, by Mr. George W. Rafter, and was
:hat time carrying about 300 cubic feet per second, or slightly over
ıbic foot per second per square mile. Mr. Rafter shows that the
r of Boardman River undoubtedly may be as low as 100 cubic feet
second for two successive months, and that it may not yield more
n 75 cubic feet per second, or about one-fourth of a cubic foot per
ɔnd per square mile, for a period of a few days.[1]

[1] Water Supply of Traverse City, Michigan, by George W. Rafter and F. H. Northrup, city engineer, 1897.

Discharge of Rice Creek at Marshall, Michigan, March 23, 1898, 1 mile above point of confluence with Kalamazoo River.

Discharge over dam	second-feet	25.
Diverted for water power	do	125.
Tributary drainage	square miles	99.
Discharge per square mile	second-feet	1.5

Discharge of Battle Creek at Battle Creek, Michigan, March 24, 1898.

Discharge over dam	second-feet	253.3
Diverted for water power	do	75.4
Total discharge	do	328.7
Tributary drainage	square miles	180.
Discharge per square mile	second-feet	1.8

The discharge a day or two previous was somewhat greater, although at that time there was an extensive flood on the flats between the point of measurement and the confluence of Battle Creek with Kalamazoo River.

Discharge of Kalamazoo River at Battle Creek dam March 24, 1898.

Discharge over dam	second-feet	648.6
Diverted for water power	do	459.3
Total discharge	do	1,107.9
Tributary drainage area	square miles	510.1
Discharge per square mile	second-feet	2.17

Combining the two preceding measurements we get 1,436.6 cubic feet per second for the discharge of Battle Creek and Kalamazoo River at Battle Creek. This, with a total tributary drainage area of 690.1 square miles, gives 2.08 cubic feet per second as the discharge per square mile of drainage area.

Discharge of Kalamazoo River at Otsego, March 26, 1898.

Discharge over dam	second-feet	234.8
Diverted for water power	do	1,669.1
Total discharge	do	1,903.9
Tributary drainage area	square miles	1,600.0
Discharge per square mile	second-feet	1.2

For purposes of comparison a measurement of Grand River was made at the North Lansing dam.

Discharge of Grand River at North Lansing dam April 9, 1898.[1]

Discharge over dam	second-feet	642.
Diverted for water-power purposes	do	560.
Total discharge	do	1,202.
Approximate tributary drainage area	square miles	1,168.
Discharge per square mile	second-feet	1.02

This was at a time of medium water when the depth of water on the crest of the dam was but 14½ inches. At the time of maximum high

[1] Probably too small, owing to impossibility of getting precise data regarding capacity of all water wheels in use.

water in later March the depth of water on the crest of the dam was shown by the water marks to have been 29 inches. This would correspond to a total discharge of about 2,365 cubic feet per second, or 2.0 cubic feet per second per square mile of drainage area.

The preceding measurements, made at different points along the stream at nearly the same time, show about the flow that may be expected in Kalamazoo River at ordinary high water. The flow per square mile apparently gradually decreases as the tributary area increases. The low flow of Battle Creek may be due to a large proportionate area of lake storage, gathering the flood waters to be yielded as run-off at a later period.

The high-water flow exhibited by the gagings was preceded by heavy rainfalls and high temperature, as shown at several stations, within the watershed, in the accompanying table:

Meteorological conditions at stations on Kalamazoo River, March, 1898.

Station.	Precipitation.						Temperature.		
	March 10 to 13.	March 18 to 21.	March 24 to 28.	Total for month.	Greatest rainfall in 24 hours.	Day of heaviest rainfall.	Maximum daily.	Minimum daily.	Mean daily.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*		°*F.*	°*F.*	°*F.*
Olivet	3.38	1.61	0.48	6.16	2.02	10	67	10	38.8
Hanover	1.07	.55	1.10	3.57	1.	28	70	1	38.2
North Marshall	.91	1.94	.78	3.83	1.44	20	69	1	36.5
Battle Creek	1.35	1.50	.....	4.21	1.50	18	69	10	38.9
Kalamazoo	1.01	.47	.51	2.32	.51	26	69	8	39.
Hastings	1.27	1.12	.52	3.21	.80	19	69	1	37.2

No snow fell during the month. On March 1 the ground was covered with about 9 inches of packed snow. This melted rapidly, and, as the ground was frozen, appeared almost entirely as run-off during the month.

Depth of snow on ground at stations on Kalamazoo River, March, 1898. (a)

Station.	Mar. 1.	Mar. 2.	Mar. 3.	Mar. 4.	Mar. 5.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Somerset	9.0	8.0	7.0	6.0	5.0
Olivet	11.0	10.0	8.0	7.0	6.0
Battle Creek	5.0	5.0	4.0	3.0	3.0
Kalamazoo	12.0	12.0	12.0	10.0	10.0
Hastings	8.0	8.0	7.0	6.0	5.0
Average depth	9.0	8.6	7.6	6.4	5.6
Average daily melting	.....	0.4	1.0	1.2	0.8

Station.	Mar. 6.	Mar. 7.	Mar. 8.	Mar. 9.	Mar. 10.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Somerset	4.0	3.0	1.0	.....	.....
Olivet	5.0	4.0	3.0	1.0	0.0
Battle Creek	0.5	0.0	.....	.....	.....
Kalamazoo	8.0	0.5	None	.....	.....
Hastings	4.0	2.5	1.0	Trace	.....
Average depth	4.3	2.0	0.8	.....	.....
Average daily melting	1.3	2.3	1.2	.....	.....

a At sunset of each day.

There are no precise data at hand relative to the low-water flow of the river. By careful inquiry from power users it was found that in nearly all cases a shortage of water occurs for from two to six weeks in the months of July, August, and September. At such times the flow is insufficient to supply the water wheels now in use to their full capacity, and is less than the amount of water shown as being diverted for power purposes at the time the measurements were made. This would be expected from the rainfall records. The following table shows the lowest recorded yearly rainfall at stations in the watershed. As the minimum observed rainfall at a station decreases as the length of the record is extended, years may be expected to occur in which the rainfall will not exceed that at Kalamazoo in 1894, or 71.5 per cent of the mean, as shown in the table. This would be 25.43 inches for the entire watershed, using our previously derived mean of 33.87 inches. For the years 1888 and 1889 the total rainfall at Kalamazoo was but 56.53 inches. The rainfall for August frequently falls below 0.1 inch, and in 1889 the combined rainfall for July, August, and September was but 3.89 inches. If the flow from full ground water were 2 inches a month it would undoubtedly have been depleted in such a drought so as not to exceed three-fourths of an inch in *a month.* As little or no rainfall reached the stream directly, the

off in the summer of 1889 must have fallen as low at least as 0.7 .c foot per second per square mile.

Years of least recorded rainfall at stations on Kalamazoo River.

Station.	Number of years' record.	Year of least rainfall.	Rainfall in lowest years.	Per cent of mean annual rainfall at station.
			Inches.	
Pulaski	4	1889	24.20	85.0
Concord	5	1888	24.17	81.8
Allegan	7	1895	26.95	75.3
Battle Creek	8	1879	20.20	74.8
North Marshall	8	1894	22.73	75.0
Hanover	9	1888	25.30	76.9
Marshall	11	1889	28.1	78.7
Kalamazoo	21	1894	26.07	71.5

HIGH WATER AT KALAMAZOO.

he extent and duration of high water at Kalamazoo is shown by following data relative to the height of the river surface during ls at that place. At the township line, 2 miles below the city of amazoo, the elevation of the bottom of the river bed is the same t the Gull street bridge within the city, there being practically no in the river in that distance. As a result, the current is extremely gish, and a portion of the city is subject to frequent floods. The k-covered river flats within the city are extensively devoted to cultivation of celery. The annual spring flood is productive of e damage, but when floods occur during the summer months they lt in a heavy loss to the celery growers and also tend to produce d sanitary condition, lasting for some time.

he following table gives the elevation of the river surface in feet ve the city datum plane. The elevation of the water surface at nean stage is 67 feet. The measurements at East avenue bridge at the point of confluence of Portage Creek with Kalamazoo River. se at Gull street bridge are below that point.

Observations of high water at Kalamazoo. (a)

Year.	Date.	Elevation.	Place of measurement.
		Feet.	
1883	June 28, 5 p. m	71.66	At East avenue bridge.
	June 29, 7.30 a. m	72.25	
	June 29, 1 p. m	72.42	
	June 29, 6 p. m	72.50	
	June 30, 7 a. m	72.74	
	June 30, 1 p. m	72.90	
	June 30, 6.30 p. m	73.03	
	July 1, 9 a. m	73.36	
	July 1, 6 p. m	73.59	
	July 2, 7 a. m	73.71	
	July 2, 1 p. m	73.71	
	July 2, 6 p. m	73.63	
	July 3, 7 a. m	73.40	
	July 18	67.88	
	August 17	68.55	
1887	February	b 74.77	
1888	July	67.55	Do.
1896	July 16	69.10	At Gull street bridge.
	July 19	68.74	
	July 31	70.69	
	August 1	70.99	
	August 3	70.49	
	August 5	69.20	
	August 8	68.99	
	August 19	69.50	
1897	March 12, 1.20 p. m	71.34	At East avenue bridge.
	March 12, 6 p. m	71.48	
	March 13, 7 a. m	71.84	
	March 13, 1.20 p. m	72.01	
	March 13, 6 p. m	72.34	
	March 14, 4 p. m	72.04	
	March 15, 7 a. m	71.54	
1898	March 14	71.35	At East avenue bridge during spring flood.
	March 15	71.80	

a These data were obtained from records furnished by Myron C. Taft, city engineer of Kalamazoo. Data for 1883 are not strictly comparable with those since that year, as an old dam has been removed and a shorter channel cut, allowing flood waters to pass off more quickly.

b Highest water recorded.

WATER POWER.

The fall and slope of the river is shown by the accompanying table. n comparison with this the next table (on page 38) shows the number f feet of fall used for water power at dams on the main river. Out f a total fall of 338 feet from Albion to Saugatuck, 76 feet is now sed for the production of power. The aggregate rated power of the 'ater wheels in use on the main river is between 4,000 and 5,000 horse-ower. This includes 18 flouring and 5 paper mills, besides planing ıills, machine shops, municipal waterworks, etc. There are also 20 ams on tributaries with a developed water power, so far as it could e ascertained, of 1,500 horsepower.

Fall and slope of Kalamazoo River.[1]

Portion of river.	Distance along river.	Total fall.	Mean slope per mile.
	Miles.	*Feet.*	*Feet.*
Albion to Marshall	12.25	52	4.22
Marshall to Battle Creek	13.25	70	5.26
Battle Creek to Kalamazoo	23.37	43	1.84
Kalamazoo to Allegan	19.73	57	3.00
Allegan to Saugatuck	32.50	116	3.55
Albion to Saugatuck	101.10	338	3.34

As has been shown, the capacity of water wheels now in use is fully ı great as the flow of the stream will warrant without the construc-on of new dams. Viewed from an economic standpoint the water ɔwer of the stream can not be greatly increased over the present ɔvelopment unless some method of flow regulation and conservation ! the flood waters be put in operation.

[1] The fall has been deduced from railroad profiles. See topography and climate of Lower ichigan, Report Michigan State Board of Health, 1878.

Water power developed on Kalamazoo River.

Location of dam.	Head or fall.	Net horse-power developed.
	Feet.	
North Branch at Horton	10	55
North Branch at Concord	9	118
North Branch at Bath Mills	8	33
South Branch at Mosherville	14	80
South Branch at Homer	8	214
South Branch at North Homer	7	69
Main River at Albion	13	298
Main River at Marengo	7	118
Main River at Marshall	6	.....
Main River at Ceresco	8	289
Main River at Battle Creek	12	469
Main River at Plainwell	19	786
Main River at Otsego	12	1,725
Main River at Allegan	8	.....

WATER POWER OF HURON RIVER.[1]

Huron River rises in the town of Clarkston, Oakland County, Michigan, and runs southwest into Livingston County, draining many lakes in Oakland County. The chief of these are White, Union, Upper Straits, Lower Straits, Pine, and Spring lakes, averaging one-half to 1 square mile in area. In the southeast part of Livingston County it takes the waters of four lakes, viz, First Base Lake, Second Base Lake, Strawberry Lake, and Portage Lake, varying from 1 to 2 square miles in area. Portage Lake is the largest and also the lowest down the valley. It is 3 or 4 miles long and averages about half a mile in width. It is fed by Portage River, which itself drains ten lakes of small size. From there the Huron flows northeast, then southeast again, and enters Lake Erie just below the mouth of Detroit River. The total drainage area is 950 square miles.

The country is flat or rolling, with a glacial drift of clay, sand, and gravel, well adapted to the raising of wheat, which is the staple and which gives work to many flouring mills. The river was declared navigable by Congress. Once a flatboat for freighting ran from Ypsilanti 30 miles to the mouth, but its use was discontinued on the advent of railroads. There was too little water for navigation, and the dams interfered. Boats run up to Rockwood, 4 or 5 miles up, on the line of the Lake Shore and Michigan Southern Railroad.

No lumbering is done, and the stream is devoted to manufacturing,

[1] From the report by James L. Greenleaf, special agent of the Tenth Census of the United States, *Vol. XVI, p. 493* et seq.

for which it is peculiarly suited. It has a fall averaging 5 feet a mile, and this near its mouth. It is on the line of several railroads, and, owing to adjacent lakes, the storage capacity is large and its flow more regular than that of various other rivers in the country. The banks of the river are usually from 9 to 12 feet high, and hence ponds do not spread. The bed and banks are usually hard clay, or a sort of conglomerate of clay, gravel, and stone (till). There is no rock bed except at Flat Rock, the first fall above the mouth.

The course is extremely winding. The Michigan Central Railroad runs along the river 17 miles from Ypsilanti to Dexter, and in that distance crosses it sixteen times. The bulk of the manufacturing is between Dexter and Ypsilanti, on the line of the Michigan Central Railroad.

At Ypsilanti the average breadth is 100 feet, the average depth 1½ feet, and the maximum depth about 5 feet. The ordinary low-water flow, calculated from the estimated horsepower, is 220 cubic feet per second, or 0.23 cubic foot per second per square mile of drainage area. The available power under 10 feet head at ordinary low water is from 225 to 250 horsepower. There is no difficulty from floating ice. A mill using the full average power of the stream can run at full capacity ten months of the year, and during August and September at half capacity. The river has no large tributaries below the lakes, and hence the power for a given fall is nearly the same in the upper and in the lower part.

DEVELOPED POWER.

Most of the mills are between Dexter and Ypsilanti, a distance of 17 miles. Above Dexter and below Portage Lake are the Hudson and the Dover mills. Below Ypsilanti are mills at Rawsonville, Belleville, etc.

Three forms of dam are in use: (1) The pile dam, a common form. A typical specimen is one belonging to the Ypsilanti Paper Company. Piles were driven 6 feet between centers, both across and down the stream, covering a strip 50 feet wide across the channel. The ends were then cut, so that taken together their surface formed two planes, meeting at the center line of the dam, like a roof. The space between the piles was filled in with stone and the top planked over. A plank apron was built on the lower side. (2) The crib-work dam—ordinary timber cribs, filled with stone and planked over. (3) The frame dam, used at the Dover mills. A triangular frame was built and planked over and stone thrown under; a plank apron was built on the lower side, and gravel thrown in on the upper side. So far as ascertained, there have been no instances of the breaking away of dams.

At Flat Rock, 7 or 8 miles above the mouth of the river, is the first power. There is about 100 horsepower available.

At New Boston and at Belleville powers are being developed. There are two flouring mills at Belleville. The banks are high and well adapted to ponding.

At Rawsonville is a flouring mill with 7 feet head. There is 150 to 175 horsepower available.

Ypsilanti is the chief manufacturing center on the river. There are three paper mills, two flouring mills, a woolen mill, and a small custom sawmill, also a low dam in connection with the city waterworks. The banks are from 9 to 12 feet high, and ponds do not spread. There are three dams, about one-half to three-fourths of a mile apart, and no fall is wasted. The bed is hard clay. The Michigan Central Railroad runs up the valley from this point, and freight facilities are good.

The lower pond has 7 feet available fall and 175 available horsepower. There is a pile dam 190 feet long. The average breadth of the pond is about 150 feet and the length half a mile. The power is utilized by the Ypsilanti Paper Company's mill. The middle pond has 8 feet available head and 125 available horsepower. The only mill at the power is the Huron flouring mill, which uses on the average 75 horsepower. There is a pile dam 5 to 6 feet high and 100 feet long. The pond is from 150 to 200 feet broad and half a mile long. The upper pond is owned by the City flouring mill and the woolen mill, and feeds them and also a small sawmill fed from the race of the flouring mill. The fall at the dam is 8 feet and the available power is 225 horsepower. The dam is from 120 to 130 feet long, the area of the pond 35 acres, and the depth 5 or 6 feet; the dam does not spread much. The woolen mill uses 42 horsepower. The flouring mill, situated on a race, has 1 foot additional fall, making the total fall 9 feet; it uses 100 horsepower. The sawmill, when running, uses about 10 horsepower.

The mills of the Peninsula Paper Company are situated at a pond a short distance above Ypsilanti, and have 300 available horsepower.

The largest power on the river is at Lowell, and it is used by the Ypsilanti Paper Company. The available head is 16 feet, and 400 horsepower is available. The pile dam has been described; its length is 166 feet. The area of the pond is 30 or 35 acres.

At Ann Arbor, 7 or 8 miles above Ypsilanti, there is a level with a head of 10 feet and 250 available horsepower. The dam is a pile dam 200 feet long, which is utilized by the Ypsilanti Paper Company's mill. Above it is another level with the same head and power. A woolen mill, a flouring mill, and a sawmill are fed from this pond, using altogether 100 horsepower. The dam is 140 feet long.

At Foster's station, 3 miles from Ann Arbor, there is a fall of 9 feet, all of which is utilized by a paper mill taking 100 horsepower and a woolen mill taking 58 horsepower. The power is estimated at 300 horsepower for six months of the year.

At Delhi there are two flouring mills, a woolen mill, and a sawmill, all using water from the same level. There is 7 feet head and 140 available horsepower. Usually all the mills can run at once. The

of crib work, 150 feet long. The Scio flouring mills are above and have 8 feet fall, with 140 available horsepower. The dam rib work, 100 feet long.

ter has a flouring mill, a woolen mill, and a sawmill, all run he same level. The available head is 5 feet. The dam is of ork, 75 feet long.

ve Dexter are the Hudson mills, with 5 feet head and 75 horse- —a crib-work dam 100 feet long,—and the Dover mills, with 7 ead and 100 horsepower—a frame dam 100 feet long. The above Ann Arbor average from 120 to 180 feet wide and one- ile to 2 miles long. There are no important powers above.

UNDEVELOPED POWER.

e are a few undeveloped powers. Three miles below Ypsilanti of 300 horsepower, which has not been used, because the pond spread over valuable farming lands and because the location is ar the railroad. One mile below Ann Arbor is a power with 4 et fall, unimproved, giving from 100 to 125 horsepower. It is line of the railroad. The small power, compared with the cost rovement and lack of demand for it, is the apparent reason it t been improved. One and one-half miles above Ann Arbor is of 10 feet, unimproved. Nearly 300 horsepower is wasted. It ed formerly by a sawmill, now burned down. It is on the line road and awaits improvement.

WATER POWER OF RAISIN RIVER.

North Branch rises in Jackson County, and the South Branch northwestern corner of Ohio. They unite east of the center of ee County and flow into Lake Erie. The drainage area is 1,162 miles. Near the mouth it is 200 or 300 feet wide, but in ordi- ater it is only from 6 to 12 inches deep, with a sluggish cur- At Adrian it is a small stream, 25 or 30 feet wide, with a ite current, about 1 foot deep. There are several small mills river, but no power of importance.

USES WHERE QUALITY IS IMPORTANT.

USE FOR DRINKING.

INORGANIC IMPURITIES.

uses of water where the quantity required is not excessive and lly readily obtained, but where the proper quality is important not so easily maintained, will now be considered. Impurities two kinds, organic and inorganic. Under the first head are sewage, swamp contaminations, ammonia, and bacteria. Salt, inorganic, has often been considered an indication of the pres- organic contamination. But in the district under consideration t true, and a knowledge of the normal chlorine percentage of the

same class of water in the same neighborhood is a prerequisite to the application of the chlorine test as indicative of sewage. Investigation of this normal percentage has been undertaken for the State board of health by Prof. D. Fall. Salt is one of the commonest inorganic constituents, only less common than the acid carbonates of lime and magnesia, which are always present except in some sandstone wells and in cistern waters. Iron in some shape, and sulphates of lime, etc., are also not uncommon in wells.

The quantity of mineral matter in the lakes or rivers is not sufficient to affect the water appreciably as a supply for healthy people, while for cases of uric acid diathesis, where lime should be avoided, many sandstone wells and shallow surface wells in sand seem specially suited, since their water contains less than the usual amount of lime. Occasionally the water from deeper wells is softer. Filtered rain water is used and is not at all unpalatable when one is accustomed to it. Distilled water is also manufactured and sold.

More detailed conclusions as to the connection between the chemical character and the suitability of a water for drinking will be found in a subsequent paper.

Dr. W. H. Deadman, veterinary surgeon at Alpena, asserts that 80 per cent of all the horse disease in northern Michigan is due to hard water. The hardness of water varies in the lakes and rivers, and probably varies with the season of the year and with the depth at which the samples are taken.

Some of the shallower rock wells, almost all those over 500 feet, and a few of the wells in drift are so highly charged with mineral matter (over ½ oz. per cubic foot) as to be cathartic or otherwise unpleasant and unfit for domestic use. It is important to note, however, that in many cases the mineral matter comes from beds of salt or gypsum, or from even less continuously porous beds, and that therefore fresh water may at times be obtained by proper casing, even under beds of salt. There are a number of cases on record in which fresh water has been obtained under salt. A notable case is that of Mr. Leipprandt, near Caseville (sec. 13, T. 17 N., R. 10 E.), who has a well 100 feet deep that is very salt, and another well 280 feet deep (cased to 228 feet) which yields good fresh water.

ORGANIC IMPURITIES.

Organic impurities are most prevalent when inorganic are least so, in the shallow wells, rivers, and ponds, and even in cisterns and standpipes. Yet even deep artesian wells are not by any means free from organic matter—for example, the Bad Axe supply. Such matter is, however, probably harmless. Organic impurities may be divided into two kinds—mere vegetable growths of algæ, etc., and the more dangerous bacteria of typhoid. The former are not wholesome, though not so dangerous as the latter, and may form in cisterns and standpipes in very [illegible] as, for example, at Bad Axe and at Leaton,

and are especially abundant in artesian water. The exclusion of light tends to check their growth in cisterns. A few cases are reported where malaria was cured by a change to drinking artesian water, seeming to show that bad water, and not bad air, was the cause of the disease. But it is of course possible that it was not the previous presence of vegetable matter in the water that caused the disease, but rather the curative properties of some mineral ingredient in the artesian water that effected the cure. Wooden or plank casing, which is much too common, soon gives a foul taste to water, and any dug well with a basin is liable to have foreign matter get into it that does not improve its quality—angleworms, frogs, mice, moles, rats, and snakes, which well drillers find on cleaning the wells.

Wells dug or driven in sand only, without a clay capping, are liable to surface and sewage contamination, though of course when they are put down 100 or 200 feet the danger is greatly reduced by the sand filtration. Even then it would be well to have the point and strainer considerably below the top of the water line. It would save trouble in an exceptionally dry year, and would give additional protection.

The practice of having any dug or shallow surface water well in a barnyard or near a privy is uncivilized and is only the temporary expedient of uneducated immigrants who have recently arrived, and one is glad to see that among the intelligent and more prosperous farmers deep driven or drilled wells are becoming the rule and not the exception. Too commonly, however, the well water of the deep driven well is allowed to flow into the old dug basin, a practice which has many objections (considered on page 73). The casing should extend from the pump to the water-bearing stratum. The well should be removed from the barnyard, to which the water may be conducted by a long launder. If a surface or dug well is the best that is available, it should be out in the orchard, and removed from sources of contamination.

Digging is sometimes the best way of sinking through a bowldery formation. A good practice, prevalent in Emmet County, is to cement the wall as the well is sunk, using a 3-foot boiler tube as a shield. Mr. E. R. Phillips, of Bay City, uses such a cemented well in the city, but he has a depth of sand and charcoal at the bottom which acts as a huge filter—an excellent palliative expedient.

Rivers and lakes are the great sources of supply for village and city waterworks, being but rarely used by individual farmers, except as some dry season forces them to haul water. Unfortunately, as we have already remarked, too often an ample supply has been considered the prime requisite for city plants.

DAIRY USE.

One great advantage of flowing wells is in keeping milk cool. The temperature of such wells approaches the mean annual temperature of the place at which they are, plus a certain small amount,

dependent on the depth below the surface from which they draw their water, about 1 degree for 60 feet. The annual fluctuations of temperature hardly affect them, though in fact if from 30 to 60 feet deep they are colder in summer than in winter. This is not only to be expected theoretically, but has been verified in practice. Professor Davis found, in studying some of the Alma flowing wells, that the water of one about 55 feet deep stood at 52° F. in winter and at 48° F. in summer.

Since the mean annual temperature of Michigan, as is shown in fig. 4, varies between 39° F. and 49° F., the temperature of flowing wells or springs should have about the same range, and the recorded observations of the shallow flowing wells are but 4° or 5° higher. This is precisely the range of temperature best adapted to keep milk. Such flowing wells may be obtained all over the Saginaw Valley, and, as the map (Pl. VII) shows, such wells, drawing water either from the rock or from gravel beds under clay, occur throughout the State. These wells yield a water very favorable to the growth of algæ, and the vegetable matter must be frequently cleaned from the tanks. Darkness checks its growth.

For use in refrigeration or for general dairy use the same purity is not requisite as in drinking water. While of course water brought in contact with butter should be free from dangerous organic impurities, inorganic mineral constituents, like salt and sulphates, are reported to be some advantage and help in hardening the butter. Much of the water of the Saginaw Valley, which is rather too salt for domestic use, is excellent for dairy purposes.

COOKING, LAUNDRY, BOILERS.

Next to the use for drinking naturally comes cooking, laundry, and boiler use. As organic impurities are rendered harmless when boiled, this factor is eliminated, except when, as is occasionally the case, "foaming" is produced in the boiler. The deposit of mineral matter in the teakettle is usually either carbonate or sulphate of lime, magnesia, or iron. If the former, a little acid quickly removes it. Iron is betrayed by its color. Only occasionally is water found with so much mineral matter as to be unfit for cooking. In such cases iron is usually the offending element, turning tea black and discoloring potatoes. Water, if allowed to stand, will precipitate most of the iron. It forms a scum which is at times mistaken for oil.

Impurities of another class, i. e., hydrogen sulphide and other gases, as well as traces of oil, occur more or less in various parts of the State. Hydrogen sulphide occurs in various places, and is characteristically common just beneath the Devonian black shales. A moderate amount does not seem to be injurious, and users soon get used to its peculiar odor; but in the deeper salt wells in the southeastern part of the State it is disagreeable, in some cases seriously affecting the eyes.

Another important consideration in regard to water is its effect on

boilers. The impurities which deposit scale are the sulphates and carbonates of lime and magnesia, and many railroads have spent considerable money to obtain purer boiler water. Water with 8 to 10 grains of carbonate of lime to the gallon is considered hard, and when there are over 40 grains to the gallon—and there are large districts where this amount is present—the water has been condemned by railroad authorities. Mount Pleasant water is typical as a bad water for use in boilers.

The sulphate of lime is worse than the carbonate. The carbonates of lime, magnesia, and iron are somewhat precipitated by exposure to the air, and further by boiling or by the addition of quicklime. In every district it will be found that the water of certain wells is considered good for threshing machines, both in quantity and in quality.

In the steam plant of the University of Michigan, which furnishes steam heat and also drives a couple of engines, the condensed water is returned to the boilers. In addition, the engineer informs me that a supply of about 400 gallons plus about 10 per cent is used daily. This is nearly all derived from cisterns, representing about eleven months' supply. I obtained, through the kindness of Professor Cooley, a blue print showing the exact roofage used in supplying the cisterns. From this I estimate that 19,493 square feet of catchment area furnishes 17,600+ cubic feet of water. This is not far from 1 cubic foot per square foot of catchment surface, or 38 per cent of the Ann Arbor rainfall (32 inches). It is impossible to estimate the amount of leakage, as there are five cisterns, scattered at considerable intervals over the grounds, and part of the rainfall of exceptionally wet seasons may overflow the cisterns. It seems as though a larger percentage of the rainfall might be saved, although the percentage of run-off to rainfall is apparently higher than in the Kalamazoo Basin. Much of the winter snow will of course slide off, and in each rain a certain percentage must be allowed for wetting the roof and for evaporation. It will be safe, however, to estimate that 10 feet square of roof surface will yield 100 cubic feet, or about 25 barrels, of water per annum.

At the Agricultural College the custom is to heat the water to boiling and then allow it to aerate, cool, and settle. At the Midland Chemical Works they propose to remove the hardness first with lime and then with soda ash.

In any case it is well to get the water as pure as possible before introducing it into the boiler; and heating the feed water with the exhaust steam and allowing it to settle will certainly help. The growth of the soda-ash industry in Michigan will doubtless permit the economical use of that chemical.

Cistern or rain water and condensed boiler water are of course free from these impurities, and it might be well to plan an agricultural engine for use in the Saginaw Valley with a condenser arranged to use its water over again and again. The soda salts, common salt, and sulphate of soda are not objectionable, but rather help to clean out

scale, and in the Saginaw Valley are often present in the water. The chlorides of lime and magnesia and the heavily carbonated waters are corrosive.

Generally speaking, the softest waters are either rainfall waters from sands so near the surface that the lime has been leached out, or waters from wells in the Napoleon and certain other sandstones, which, even when salt, run much lower in sulphates than do the waters of the higher beds.

What has been said concerning cooking and boiler feed water applies also to that for laundry use. The prevailing hardness of the water has led to the extended use of cistern water for washing. If one-third the rainfall can be saved, a roof 10 feet square will yield about 600 gallons a year. It is only in part of the sandstone district that the wells are so soft that there is no object in saving rain water. To supplement rain water very shallow wells are sometimes used, when only 2 or 3 feet of sand is underlain by clay and has been washed free from lime, so that one can get practically surface rain water. In a fresh cut in a gravel bank (e. g., at Mecosta), the leaching out of the lime and iron from the first 2 feet or so is well marked by a dark line at the bottom where the lime and iron are concentrated, which have often cemented the pebbles together into one form of "hardpan," a term also applied to till.

The same remedies for hardness mentioned above, viz, exposure to air, boiling, and the addition of quicklime or sal soda, are also available in laundry use, and are known as "breaking" the water.

It is advisable to get the water as pure as possible before its injection into the boiler, rather than to rely entirely on "dosing" the boiler.

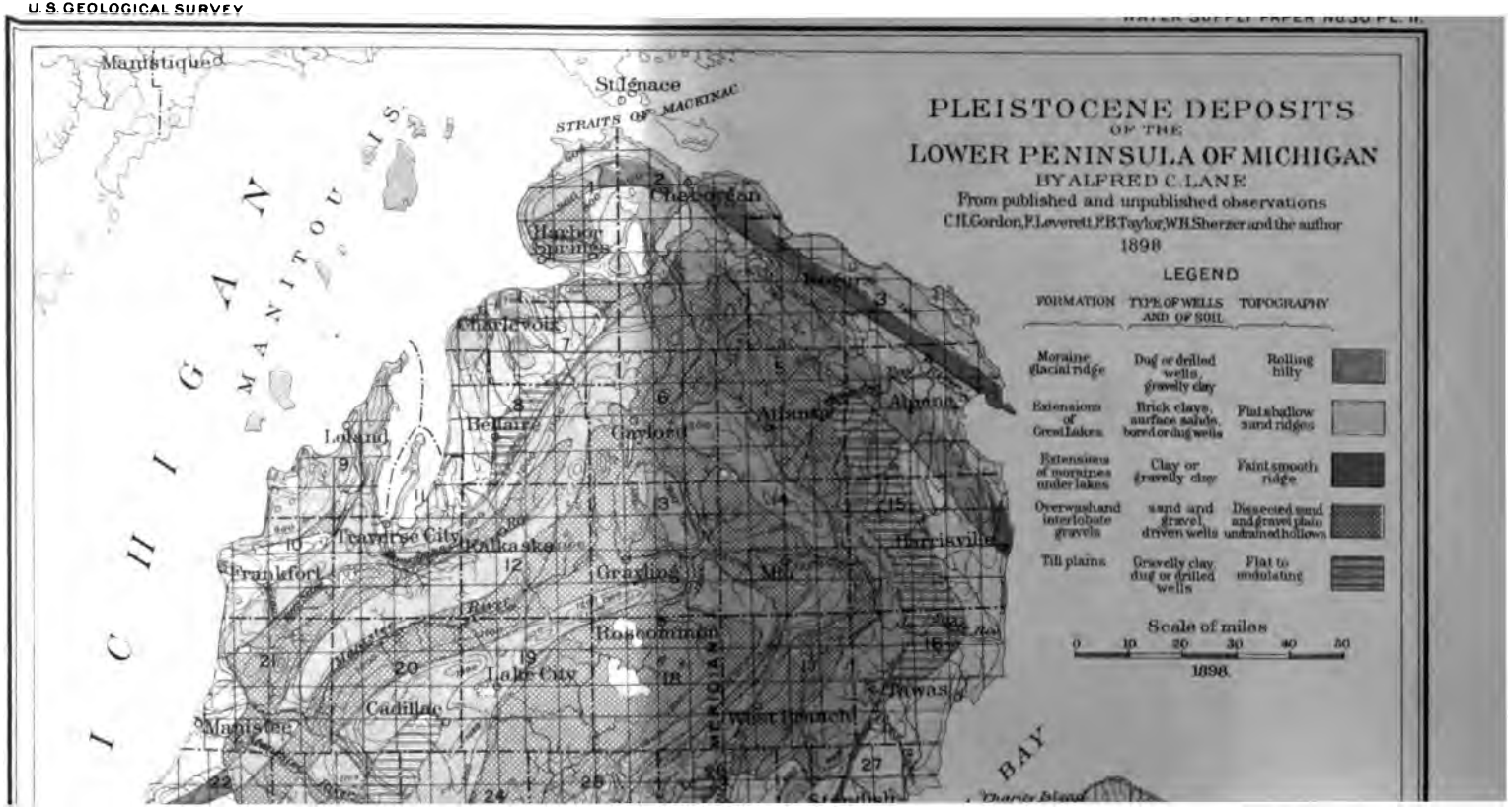
SUGAR-BEET INDUSTRY.

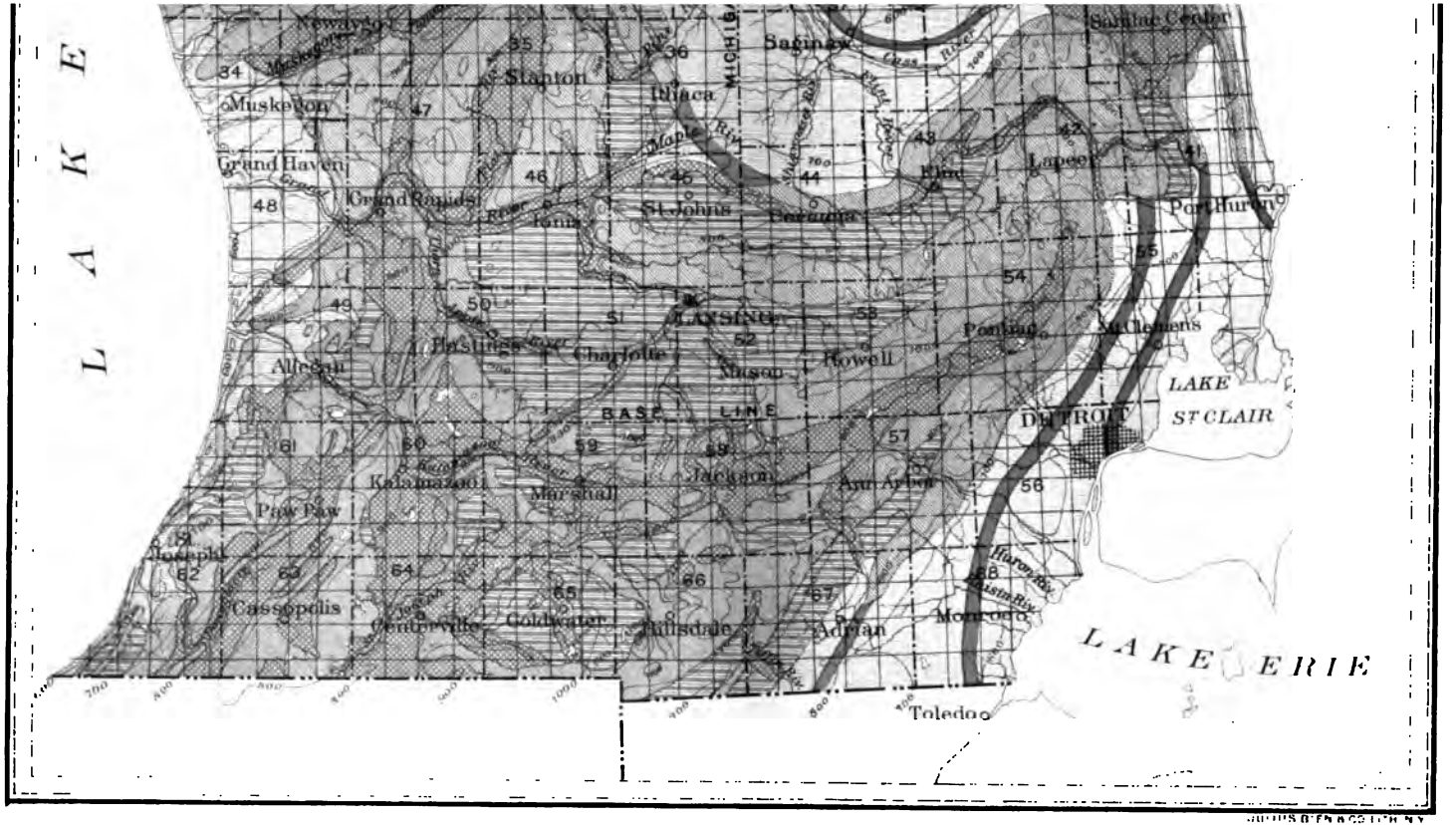
In the manufacture of beet sugar it is important to have a water as free as possible from salts, for every molecule of chlorine salt is said to invert about five molecules of sugar into glucose. Organic matter is said to work in like fashion. None of the surface waters, and but few of the deeper drift wells, are really disqualified, although there is considerable difference between them. Most of the deeper rock wells, however, over 300 feet in the rock, except those in the northern part of the State and, relatively speaking, the waters of the coal basin, would be unsuited for such use. A great deal depends on prompt handling and skill.

PHOTOGRAPHY AND OTHER USES.

For photography, paper making, wool scouring, and manufacturing industries generally it is important to have as little mineral matter as possible. For photography rain water can be used only if fairly free from organic matter. Photographers frequently use the common *hard water*. One possible exception to the general rule that sulphates

2


PLEISTOCENE DEPOSITS
OF THE
LOWER PENINSULA OF MICHIGAN
BY ALFRED C. LANE
From published and unpublished observations
C.H. Gordon, F.L. Leverett, F.B. Taylor, W.H. Sherzer and the author
1898
LEGEND
FORMATION
TYPE OF WELLS AND OF SOIL
TOPOGRAPHY
Moraine, glacial ridge
Dug or drilled wells, gravelly clay
Rolling hilly
Extensions of Great Lakes
Brick clays, surface salds, bored or dug wells
Flat shallow sand ridges
Extensions of moraines under lakes
Clay or gravelly clay
Faint smooth ridge
Overwashand interlobate gravels
sand and gravel, driven wells
Dissected sand and gravel plain undrained hollows
Till plains
Gravelly clay dug or drilled wells
Flat to undulating
Scale of miles
0 10 20 30 40 50
1898.
Manistique
St. Ignace
STRAITS OF MACKINAC
Cheboygan
Harbor Springs
Charlevoix
Bellaire
Gaylord
Atlanta
Alpena
Leland
Traverse City
Kalkaska
Frankfort
Grayling
Mio
Harrisville
Roscommon
Lake City
Cadillac
Manistee
West Branch
Tawas
LAKE MICHIGAN
MANITOU IS.
BAY


LAKE
Newaygo
Stanton
Muskegon
Grand Haven
Grand Rapids
Ionia
Ithaca
Saginaw
Saginaw River
Tittabawassee River
Maple River
Flint
Lapeer
Port Huron
St. Johns
Owosso
Pontiac
St. Clemens
Hastings
Charlotte
Howell
Allegan
BASE LINE
DETROIT
LAKE ST CLAIR
Kalamazoo
Marshall
Jackson
Ann Arbor
Paw Paw
St. Joseph
Cassopolis
Centreville
Coldwater
Hillsdale
Adrian
Monroe
Huron River
Raisin River
LAKE ERIE
Toledo
MICHIGAN

are deleterious in manufactures is ale, in which, it has been said,[1] a certain amount of calcium sulphate is an improvement. Generally speaking, however, the breweries take great pains to get as pure water as possible. In compounding medicines also a pure water is of importance. The industries (salt, potash, bromine, and mineral water) dependent on minerals in the water are not here treated.

The industries requiring pure water are well worth consideration in reenforcing the demand for pure water and in estimating the availability of several possible supplies. Of course pure water is important to those seeking the most favorable location for such industries.

QUALITY AND QUANTITY COMPARED.

It may be said in general that while for uses which look first to quantity the lakes and rivers are the natural source, for freedom from organic impurity the deeper wells have the preference. Water from both these sources, except from some sandstone and coal measure wells, is rather hard, so that for washing cistern water is preferred. The deeper the well the greater the inorganic impurity, with some noticeable exceptions, chiefly in that the waters from the Napoleon sandstone and the Dundee limestone, down to the Sylvania sandstone, may be less charged than the waters from beds above.

The Great Lakes, with properly located and guarded intake pipes, furnish a good city water supply. The supply from all rivers, even the Detroit and St. Clair, should be filtered. Many towns fortunately possess an ample supply from deep wells. Only in that territory which lies at the same time in the region of the old lake bottoms, colored blue on the map (Pl. II), and that of the Coldwater shales (see Pl. VI) is the outlook for deep-well supply entirely unpromising, so that carefully filtered river water or aqueducts from springs near the flank of the nearest moraine seem the most hopeful sources of large supply for towns.

Statistics show that city use is generally extravagant, rarely less than 100 and rising to 200 and 300 gallons per capita a day. This is much more than domestic use requires, and is due partly to uses where quality is comparatively no object, such as street sprinkling and fire protection, the use of lawn hose and of water for elevators and light machinery, etc., but largely to sheer waste. It is not for the public welfare to stint the use of water to the detriment of cleanliness, but it is advisable to stop waste, and the effect of meters in this respect is wonderful. It would be well to have a minimum price for a certain quantity, say 30 gallons a day for each room served, to prevent undue economy, and after that charge in proportion to the amount of water used. It is a question, also, whether the more wealthy residents who use the lawn sprinklers freely pay more or less than their fair share of the water rates at the present schedules.

[1] See Ency. Brit., article Burton.

Some few towns, like Rochester, possess an ample supply of unexceptionable water, though even in such cases a prudent provision for the interests of posterity would guard against the waste which has already lowered the head in some communities to a dangerous extent. A flowing well is valuable, and the head needful to produce one should not be recklessly wasted.

Most of the smaller towns, however, stand on a border line. They can get a supply of well water which will suffice for ordinary and economical use but not for emergencies. This is a field for reservoirs and for filters. It should be remembered that the efficacy of a filter depends very largely on its not being used constantly, but allowed, as it were, to rest from time to time. Filtration of a lower grade supply is especially adapted for extraordinary demands. The ordinary supply of such towns as Alma and Mount Pleasant should be from deep wells, but in case of fire filtered river water might be turned in. To use unfiltered river water without notice to consumers ought to be out of the question. Accustomed as people may be to the better supply they will not use the same precautions as if they had the poor supply regularly. In the Manual of American Waterworks it appears that there are many towns which, in case of fire, pump directly from the river.

Lower Michigan is so situated with respect to the Great Lakes that most of the larger towns can derive from them a satisfactory supply by using proper precautions. Many others can derive a domestic supply from the Marshall sandstone. Only along the Saginaw River is the question of water supply at all serious. Saginaw Bay is exceedingly shoal, and for East and West Saginaw and Bay City the supply can not be regarded as at all satisfactory.

It seems, however, that there is destined to be a city of the first rank along Saginaw River. Even if from the sandstones (not merely the drift which has been tested unsuccessfully by the waterworks experimental wells) a sufficient supply of water relatively free from mineral can not be obtained,[1] it seems certain that to the west and southwest, in Tuscola County, less than 25 miles away, the water resources can be utilized for a metropolitan water supply.

CLIMATE.

The most detailed account of the climate of the State is by the former State geologist, A. Winchell.[2]

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[1] The recent explorations for coal and city wells show that here and there in channels there are within the first 200 feet beneath Saginaw areas of water-bearing sandstones.

[2] Tackabury's Atlas of the State of Michigan, edited by H. F. Walling. First edition, 1873; second edition, 1884.

Proc. Am. Assoc. Adv. Sci. (Troy meeting), August, 1870.

Harper's Magazine, Vol. XLIII, July, 1871, p. 275.

Wegweiser der Michigan, Hamburg.

Oesterreich. Ges. für Meteorologie, Wien. Zeitsch., Bd. VIII, February 1, 1873, p. 40.

From Winchell's work much of the material in this chapter is abstracted. It is, of course, not wholly up to date, but Prof. E. A. Strong, of Ypsilanti, director of the State weather service, who has studied and compiled the later data, informs me that they are substantially correct, and I am indebted to Mr. C. F. Schneider, director of the State weather service, for additional figures.

The most notable features of the climate of the Lower Peninsula may be summed up in a few words by saying that it is what its name implies, pene-insular, modified by the fact that it has greater relief than the neighboring States to the west. The mean temperature for the year is higher on the east shore of Lake Michigan than on the west shore, as is also vividly shown by Winchell's isothermals of the extreme minima, and in this respect, owing to air drainage, the highlands have an advantage over the lowlands, the central part of Michigan being better off than St. Louis, so far as the extreme cold of winter is concerned. In fact, the mean of January temperature is higher and of July heat lower than farther west.

It is obvious that these facts have a bearing on the run-off of the streams. The amount and distribution of the rain or snow must also be taken into consideration. This has been carefully studied for the Kalamazoo River by Mr. Horton in a previous section, page 26. The average precipitation for the Lower Peninsula is some 32 inches. The heavy dews which occur in some parts of the State need not be taken into consideration as run-off, however important they may be for the farmer, because they are largely evaporated or absorbed by plants and do not become a part of the water resources. Some idea of this factor might be obtained from the relative humidity of the air, but as to actual rainfall the Lower Peninsula is in about the condition of Wisconsin. The distribution of this precipitation is also of interest. The contrast in the winter between the upper and lower parts of Michigan has frequently been observed. The region of Lake Superior will be buried in snow 2 or 3 feet deep when through the lower part snow is found only in scattered patches. Winchell gives the following table:

Distribution of precipitation in Michigan by seasons.

Season.	Upper Peninsula.	Lower Peninsula.	The State.
	Per cent.	*Per cent.*	*Per cent.*
Spring	19.	25.8	23.8
Summer	27.	28.7	28.3
Autumn	28.8	27.3	27.7
Winter	22.	19.1	20.
Total	96.8	100.9	99.8

Taking into consideration both the milder climate and the marked diminution of precipitation in winter, the table above indicates less accumulation of snow during the winter. Thus the spring freshets are much less decided than in many other States, while the temporary winter snows largely sink into the ground. From this results a steadier flow and less erosion and fewer flood plains in the streams than would otherwise be the case. The many lakes without outlets would fluctuate

even more violently were this not the case, and doubtless be more likely to cut channels for themselves. The abundance of lakes also helps to keep more uniform the flow of the streams. The effect of cultivation, on the other hand, is to make the spring freshet sharper and earlier, for the snow disappears first from plowed fields and cleared lands.

For the four figures (figs. 2 to 5) illustrating Michigan climatology I am indebted to the director of the Michigan weather service, Mr. C. F.

FIG. 2.—Distribution of average minimum temperature in Michigan.

Schneider. They are compiled from the records of the various stations (about 108 in all), and are the result of averaging all the data on file in the office, in general covering a period of about ten years, except for the precipitation chart (fig. 5), which covers a much longer period. The period of observation is not the same for all stations. The temperature observations at Lansing go back to 1873.

Fig. 2 shows the average of the average diurnal minimum temperature for each year.

The mollifying effect of the westerly winds blowing off Lake Michigan and Saginaw Bay is very apparent. The highlands northwest of Saginaw Bay have extremely low minima, as might be expected, while those southeast, on the contrary, have not so low minima as the Saginaw Valley, and it appears that the valleys draining thither have, on the whole, lower minima than those draining southeast.

FIG. 3.—Distribution of average maximum temperature in Michigan.

Fig. 3 similarly gives the average of the average maximum temperature during each year. At the northern end of Lake Michigan the maximum as well as the minimum temperature is raised, and the general average is abnormally high (fig. 4). At the lower end, however, the maximum and the mean temperatures are but little raised, so that the lake serves only to mollify the frosts of this fruit belt, changing the climate, as a whole, only as it becomes more equable. The two highlands have opposite relations to the maxima; the one northwest of Saginaw Bay has specially low maxima, while the one southeast

is distinctly higher. The former is sandy and largely covered with barren, denuded jack-pine plains; the latter is lower, more clayey, more cultivated, and probably retains its moisture—the great regulator of climate—better.

Fig. 4, showing the mean temperature, indicates that warmth enters from the southwest corner of the Lower Peninsula and extends up Grand River Valley, while the temperature at Saginaw is rather

FIG. 4.—Distribution of average mean temperature in Michigan.

colder than it is immediately east or west. The mollifying effects of Lake Erie and Lake St. Clair are also shown in figs. 3 and 4. It is generally supposed that, as stated below, the temperatures of flowing wells are those of the localities given in fig. 4, plus a certain amount, this amount depending on the depth of the well—about 1 degree in 60 feet, but observations give rather higher temperatures in wells less than 200 feet deep. The summer rains may penetrate farther and more rapidly than do the winter snows.

Fig. 5 shows the average rainfall. In the southern part of the

peninsula precipitation and temperature seem to increase together, while in the northern part of the peninsula a line of low precipitation seems to extend from Saginaw Bay to Grand Traverse Bay. It is a fortunate coincidence that the flat, low, clayey, easily flooded Saginaw Valley has a relatively low record in precipitation as well as in temperature, while the sandier western shore has more rain.

The wind has some influence on problems of water supply. Many wells are said to change their level with the wind. This is probably

FIG. 5.—Distribution of average annual precipitation in Michigan

in many cases not directly due to the wind but to fluctuations in barometric pressure. The prevailing winds have another very important effect. Where the prevailing wind is on shore, the shore is more apt to be sandy than where the wind is offshore. A large part of the peninsula has been covered by lakes and the sandy character of the shores and old shore lines that face the west, which is the direction of the prevailing wind, is pronounced. It should be remarked, in addition, that during the hot days of summer a marked afternoon breeze from the lake is a prevailing feature.

LONG-PERIOD VARIATIONS IN RAINFALL.

There is one important feature of the climate, however, on which no light can be gained from Winchell—the variations of the annual rainfall from year to year. This may be learned from the fluctuation of the ground-water level, or the level of the Great Lakes, which observation has shown (see fig. 1) rise and fall according as the general rainfall of the previous years has been more or less than the average. When the rainfall for several years has been below the average there is also a fall in the level of underground water and in the level of the lakes, especially those that have no outlets. Clam Lake, near Cadillac, has varied 16 feet within memory, and Houghton Lake and Higgins Lake are lower than they have been. One will everywhere find reports that the lakes, streams, and wells are lower than they were formerly, and muck plains (Pl. III, *B*) underlain by shells, marking former lake bottoms may be seen. This lowering of lakes and ground water is ascribed to various causes, all of which may perhaps be at work.

In the first place, it is argued that cultivation tends to accelerate the run-off so that water does not have time to soak into the earth. This is doubtless true. On preliminary railroad profiles, for instance, areas are marked "swamp" or even "all water" which are now fertile fields by no means damp. The original Government field notes of the United States Land Office also show areas marked "swamp" which are far from such to-day. Much discussion and many charges of fraud concerning these "State swamp lands" have arisen, but not all such descriptions were by any means fraudulent. Many of these swamps are explicitly described as beaver meadows or as due to beaver dams. The beavers have gone, their dams have been broken, and the swamp has become dryer. Again, loggers' operations are active in clearing out the streams and in cutting out the dams, though they erect dams and obstructions of their own. On the whole, however, the floods, aided by the loggers, have cleared the streams and made them more efficient drainage channels. The more irregular the flow of a given quantity of water the greater its efficiency as an erosive agent.

The next cause to be considered is devastation by fire. Logging operations leave the forest a forest still, but the black scourge of fire which follows strips the ground of leaves, and, worst of all, frequently consumes the vegetable mold that absorbs water like a sponge. The amount of water actually evaporated by a fire is insignificant in proportion to the permanent damage. Most of this fire waste is accidental, but some of it is the result of gross carelessness. I have seen a meadow with the mold of generations burned clean in clearing, leaving only a bare subsoil of sand fertilized with ashes that will yield good crops for a few seasons only and then be leached out. Then comes the plow. Sandy soils still absorb water, some of them having 36 per cent water capacity, but some of the bare, plowed,

A. CLINTON BORING APPARATUS.

B. FIELD OF ONIONS IN DRAINED LAKE BOTTOM: 1,350 BUSHELS TO 1½ ACRES MUCK PRACTICALLY BOTTOMLESS.

un-baked slopes of the clay hills are almost impervious to water. 'inally, in the extreme lowlands drains of every size and variety, from he farmer's tile drains to the roadside, the township, and the large ounty drains, accelerate the departure of undesired water.

The time may come when drainage, instead of being down the slopes, ·ill be along them, transferring the water from the hollows to the ›wer uplands and thus promoting irrigation. But that time has not et come.

In the second place, there is often supposed to be a general desiccaion of the climate, a steady decrease in precipitation. Of this there ; no definite historic evidence, though of course in the ice age and mmediately subsequent there was certainly more water in all lakes nd rivers, though possibly no greater precipitation. Frozen water nce covered the country. Legends of what the Indians used to do in he way of canoeing can be easily interpreted, partly by the desiccation ıue to settlement (which has already been mentioned) and partly by he fluctuations of precipitation and water stage from decade to decade. But as research shows, the general water level has been fairly contant during the century. A period (1886–1896) of decreasing rainfall, ıowever, which has just been passed, has lowered the lakes and caused he wells to fail in a way that has surprised the oldest inhabitants ıf many of the new towns. It is necessary to go back many years for ı similar fall.

SHORT-PERIOD FLUCTUATIONS IN WATER LEVEL.

Sudden fluctuations occur in the Great Lakes and in the ground vater which are not regular annual and seasonal fluctuations like those ›efore described, but are more like waves of great breadth, the whole vater of the lake basin washing from side to side. An instance may ›e recorded in which the surface of a channel connecting a small lake vith Lake Superior rose and fell about a foot in an interval of twenty ninutes. Similar fluctuations occur everywhere in the lake and com›letely disguise, except to most careful and systematic observation, he minute lunar tides. Sometimes these variations can be distinctly raced to the wind. A strong north wind will pile the water up in Saginaw Bay, and a strong southwest wind will drive it out. A variaion of 400 feet in the position of the shore line has thus been caused n one night. Another cause of these variations, often cooperant with he one just mentioned, is a variation of atmospheric pressure over lifferent parts of the lake basin, the water tending to rise when the ›ressure is least.

Analogous phenomena, probably due to analogous causes, are eported from numerous wells, but as yet have not been subjected o careful investigation. When the wind is in a certain quarter ong enough or strong enough, or just before a storm (i. e., at a ime of low atmospheric pressure), the water is reported to come

more freely, to have greater head, or to be roily. These phenomena are naturally most conspicuous in wells which flow with no great head, and are analogous apparently to those long noted on Stromboli and Vesuvius, which are said to discharge their lurid contents more freely before a storm. Sometimes these phenomena are attributed to direct connection with the lake. This theory, of course, ought not to be rejected in all cases; but similar phenomena occur so far from the lake that it is safe to assume that in most cases the well fluctuations are due to the same cause as the fluctuations in the lake rather than to the fluctuations themselves. An interesting "breathing" dry well is noted in sec. 7, T. 35 N., R. 5 E., a phenomenon which has been noticed in caves elsewhere in the world.

WELL TEMPERATURES.

Special attention is due to the effect of mean annual temperature on the temperature of wells and springs. It is true in general that the temperature of the water in flowing wells or springs represents the mean temperature of the locality, but there are some qualifications; something must be allowed for the increase of temperature which we find everywhere in going toward the center of the earth.

If the rate of increase shown by the Alma Sanitarium deep and shallow wells gives a true average, we get an increase of temperature of about $(98°-48°=50°)\div(2863-157=2706)$ or 1° in 54 feet, which is very nearly the normal rate of increase of the world, which may be assumed in preliminary reductions. Other wells at Midland, Saginaw, Frankfort, etc., would give other rates down to 1° in 100 feet, but they are for less depths. Water flowing from a driven well 56 feet deep, therefore, might have its temperature raised about 1° above the average for the place, provided it had been flowing so long or in so strong a stream that the temperature of the ground traversed on the way up did not affect it. The effect of the summer's heat and the winter's cold is felt in the ground (as Lisbon and Edinburgh observations have shown) to a considerable depth, the annual variation growing less with increased depth and the time of greatest cold becoming later, so that if the flow is from 30 to 60 feet down the temperature should be actually slightly lower in summer than in winter. Observations by Prof. C. A. Davis, of Alma (T. 11 N., R. 3 W.), show this to be the case in some of the wells there, the water of a well 55 feet deep standing at 52° F. in winter and at 48° F. in summer. Other observations of the temperature of wells require modification to allow for the above factors. But it is certain that the temperature of water from a well 100 feet deep ought not to vary more than 2° F. from the mean annual temperature of the place, and probably in summer, when observations are usually taken, is very near it, the effect of the last winter's cold balancing that of the earth's thermal gradient.

The temperature of deep-flowing wells of small bore is somewhat affected by the earth's heat, e. g., the deeper Bay Port (T. 17 N., R. 9 E.) wells; but it would certainly be incorrect to take anything near (338 ÷ 56 =) 6° from their temperature (of 47° F.) to obtain the mean temperature of the place. Again, as the winter temperature is felt to a depth at which no effect of a particular cold day or week can be detected, so a series of extra cold or extra hot years will modify the temperature to a depth where no trace of annual fluctuation can be observed. In a similar way any permanent factor, like the presence of a boiler house or a cellar furnace, may modify the temperature of a flowing well to a considerable depth. A good illustration tion is afforded in a flowing well at the sawmill in Rose City (fig. 8), which is deeper and on ground 25 feet lower than the wells of the town; but this is not sufficient to account for nearly 7° greater warmth over the hotel well.

SUPERFICIAL GEOLOGY AND TOPOGRAPHY.

GENERAL DESCRIPTION.

The contour map of the State (Pl. I) shows two high areas, to the southeast and northwest of Saginaw Bay, respectively, which are also brought out in fig. 6. Winchell has laid down the following proposition (Tackabury's Atlas of Michigan, p. 14): "The actual topographical and hydrographical axes of Michigan and the whole lake region are the resultant of two forces—a glacial, acting from the northeast, and a stratigraphical, acting along the lines of strike of the rock formations." This is what he calls the diagonal system in the physical features of the State. While this statement may be true in a broad way, it must be seriously modified to express the facts of the case. It ignores the shore lines of the old lakes, elsewhere recognized by Winchell as an important factor, and it is really as approximately true that the various positions in Michigan where the glacial front halted, i. e., the moraines, and more or less at right angles to the direction of its motion, are the dominant features, and that next to them come the lines of halt of the lakes succeeding. The old stratigraphic lines of rock outcrops are very obscure.

In a broad way, as described by Winchell, the consolidated rocks are arranged in concentric circles, surrounding the coal measures which occupy the center of the State. (See map, Pl. VI.) During Mesozoic and Cenozoic time these were eroded, but two sets of strata proved to be sufficiently resistant to become topographic features of the first class. The Marshall sandstones (Logan conglomerate), the Helderberg in the southern part of the State, and the Traverse limestones in the northern part of the State, tended to make ridges, as may be seen in the cross section (fig. 10). Inasmuch as the softer coal basin rocks were thus surrounded by harder strata this harder rim

would be cut across in some way. The evidence seems strongly to indicate that the channel draining the central basin went off, not as Spencer has suggested, through the Saginaw Valley, but past Manistee toward the great valley, now occupied by Lake Michigan, which was excavated in the softer shales, gypsum, and salt, and marks the Salina (Lower Helderberg). The circumvallation was probably somewhat broken in the region of Saginaw; at any rate, the outer circle made by the Helderberg (Traverse, Dundee, and Monroe limestones) was passed. Thus the ice flood, advancing from the Laurentian highlands, was deflected by this circular double rampart and passed in two great lobes—the Michigan and the Huron-Erie respectively—west and east of it. As the ice reached its maximum, however, it broke over the outer rampart and passed down the present valley of the Saginaw. At the greatest extent of the ice Michigan was completely and undoubtedly smoothly covered with it. Of inter-Glacial periods, with accompanying forest beds and other deposits interstratified with the till, the evidence is not very clear in Michigan. This is a point of importance, as such inter-Glacial beds might be water-bearers. The red clay described by Rominger may be such an inter-Glacial formation. Wood, however, is not uncommonly found in boring wells, as at Vassar, at Paw Paw, in Huron County, and elsewhere.

A bed of gravel or bowlders, which is porous compared with the overlying till, generally comes just above the bed rock, and the till itself is sometimes composed of alternations of gravelly clay and sand or quicksand. Such alternations and buried wood might be explained by the oscillations in the advance and retreat of the ice front and by the shifting of the ice streams from season to season, decade to decade, or century to century. It should be remembered, too, that caution must be used in interpreting the results of mere borings. For instance, a 3-foot seam of sand, reported in a 2-inch boring near Saginaw, when a shaft was sunk proved to be merely an irregular, nearly vertical seam.

It can not be said that below the present surface of the drift such an oxidized and eroded surface has been detected as would plainly imply an inter-Glacial period of considerable duration. Such a surface, especially near the center of motion, would often be swept away and obliterated by the readvance of the ice, and I have seen few exposures which indicated it, for erosion has not gone very deep since the last disappearance of the ice. The cliffs north of Frankfort, and particularly the valley of the Au Sable, would seem most hopeful places for the search. I should be puzzled to know how to make sure of its existence from a mere well record, unless, perhaps, such a zone being reached might be recognized by the yielding of softer water than that of the strata above.

The comparative lack of evidence of inter-Glacial epochs in Michigan, compared with States farther south, can not, however, be wholly

accidental, and the advance of the ice may be likened to the tides rising and falling on the shore. The highest tides of spring extend farther than the others, and the intervals between such extreme tides are at least half a year. Lesser high tides occur twice a month, and the common tides ebb and flow every day. So, down the beach, areas but rarely reached by the waters and uncovered most of the time, adjoin those generally covered by the waters. Thus, along the Ohio River—the line of the greatest extension of the ice—its presence must have been comparatively brief and its visits few, while in Michigan, nearer the source of the ice, the inter-Glacial periods may have been partly or wholly absent and certainly must have been shorter. When the ice finally retired, a lobed arrangement of the ice front—two large lobes on each side of the Marshall circumvallation and a smaller one, the Saginaw lobe, passing directly over it—were conspicuous and remained the most important features in determining the topography of the State. (See map of the Pleistocene deposits, Pl. II.)

The general theory is that the ice retired first from the higher lands; the Saginaw ice lobe, therefore, retired first, and bounding it on each side were two deeply reentrant cusps, which may be said to be the topographic axes of the State. Naturally, streams issued from such cusps, draining away the water from the wasting glacier, so that the typical form in which cusps appear is that of a stream valley, much wider than the present stream, charged with gravel and bowlders—valley trains—and heavily belted with moraines. This concentration of till and detritus on the highest parts of the rock floor naturally forms the highest parts of the State (see fig. 10).

The eastern cusp follows fairly closely the dividing line between the drainage into Lake Erie, Lake St. Clair, and Lake Huron (direct), and the drainage into Saginaw Bay and Lake Michigan. It, and also the other cusp, is marked by a belt of country crowded with lakes. Of the western cusp, Mr. Leverett thinks that he can determine the moraines on the Michigan side from those on the Saginaw or east side, by the fact that the latter contain many more pebbles of a bright red jasper conglomerate.[1]

Thus, at the extreme southwest of the State, where the cusp first entered, Mr. Leverett refers to the Saginaw lobe, because it bears many red jasper-conglomerate pebbles, the morainic belt (see Pl. II) which passes northeast from Niles and goes through Kendall, in the northeast corner of Van Buren County. Therefore the first position of the cusp would lie between it and the stronger ridge just west, which undoubtedly belongs to the Michigan lobe and is known as the Valparaiso. In confirmation, Mr. Bate, a surveyor of much experi-

[1] My own observations agree so far as they go, but the fact is singular. The conglomerate and jasper in question appear to come from the original Huronian area on Thessalon River in Canada, and one would think that they would find their way rather into the Michigan than into the Huron-Saginaw lobe.

ence in the region, states that the red jasper-conglomerate is abundant in Montmorency County, but scarce or absent in Otsego County, except near the eastern line. It is to be noticed that on the map (Pl. II) these moraine belts have their separate color, and the more important areas of sand and gravel deposited by streams draining the ice front are also delineated, although many smaller areas of gravel and sand and stream channels are, for the sake of clearness, omitted. A different color is devoted to those areas over which the ice front retreated more rapidly, making less conspicuous ridges.

Both cusps were evidently guided by the higher land of the Marshall sandstone outcrop. As the eastern cusp worked northeast the upper valleys of the two St. Joseph rivers, the Tiffin (whose drainage area has been preyed on by the Raisin), and the upper Huron River above Dexter, which probably drained off at one time past Adrian and possibly earlier found its way into the Ohio, were successive outlets of discharge. Farther northeast the drainage has been largely rearranged, though the upper parts of the Clinton River, and later the northern forks of the Flint River, the Cass River on the Saginaw Valley side, and the Black and its branches on the other, served for a time. The old summit swamp referred to by Taylor[1] may also be mentioned, and in Huron and Tuscola counties a number of channels are known which evidently drained the ice front but are too numerous to be indicated in a general map. High deposits near the angle are found at Metamora, between Deanville and Brown City, and near Verona Mills.

For the other cusp Dowagiac Creek served at first and, with St. Joseph River, poured into the Keokuk that vast expanse of gravel which is found in its upper reaches in Indiana. Then passing north, through a belt full of lakes, down the valley of the Thornapple, it may be followed up the valley of Flat River, and past Mecosta into the Muskegon Valley. In the Muskegon Valley there is a stream which, first by way of Mecosta and Barryton and then by the main stream, received the cusp drainage for a considerable time. Thus the cusp may be followed into Oscoda County. From this point on the original cusp-drainage lines have again been so disturbed and reversed that it is hard to trace them. Probably the high points near Otsego Lake were at one angle. An old channel seems to pass near Valentine Lake. But the ice soon retired and allowed the water to flow freely all around the peninsula.

The lines of retreat of these cusps are bordered with moraine hills, composed of the débris left by the ice front where it tarried long or readvanced. Moreover, the ranges of moraine hills are crowded together and are higher toward the lines of cusp retreat, for, these hills being nearly parallel to the direction of ice advance and retreat, a general advance or retreat in the ice front made only a slight differ-

[1] Geol. Soc. Am., Vol. VIII, 1896, p. 31.

ence in their position. Of course such moraine belts are studded with small tarns—deep lakes of water caught between the various rows. Some of the moraines, especially the higher ones, which do not mark readvances so much as the edge of the cusp dump grounds, are exceedingly sandy, with hardly any clay, and in such cases the lakes fre-

FIG. 6.—Sketch map of the drainage of Lower Michigan.

quently have no outlets. Lakes of another variety are formed in the following way. The moraine belts are frequently cut through by channels which served as vents for streams coming forth from the moraine. Only a few of these channels are indicated on Pl. II. One, well marked, is formed by the upper valley of Willow Creek in T. 16 N., R. 13 E.,

Huron County, which also has branches. Four Harbors, in Clare County, are others, some of the finest that I have seen. Entering the valley of the South Branch of Muskegon River there are others, in T. 24 N., R. 4 W. But many that I have noticed I have not yet been able to connect into significant channels. Now, while sometimes the old channels abandoned by the streams from the melting ice sheet stand perfectly empty, more often they are occupied by marshes at least, and not infrequently by lakes, the hollows occupied by the lakes having been made by the melting of a lump of ice (kettle-holes), by irregular settling of the sand, by an original sand bar in the stream, or by delta sand washed in by some tributary Glacial or post-Glacial stream. Many of the long, winding, and generally shallow "crooked" lakes, are thus located.

It is obvious that thus to uncover and drain the higher lands must produce, first of all, a peculiarly unnatural form of drainage. A marked type of river valley is thus produced. (See fig. 6.) All the larger streams begin to flow to the south, starting from some of the lines of drainage from the ice. They run along the ice front opposite a moraine, which, as a comparison of fig. 6 and Pl. II shows, is often a divide, and receive, of course, some tributaries from the north, which usually flow in valleys of ice outlets, but also receive a great many streams, perhaps smaller individually, which flow down the back of the moraine last deserted. At some point in their flow they reach the old lake shores, unless they are first diverted by some stream which has cut back through the moraine, and thence flow more directly down to the present lake. This accounts for two of the most striking facts in studying the drainage of the Michigan streams, namely: (1) The principal stream valleys run as a rule southward; (2) the principal streams receive more tributaries in branches from the south. The Maumee is a most striking illustration of this tendency, while the Bear and the Betsie, Au Sable and Boyne, near by, are similar. But so far as the rivers are concerned, hardly anything can be more striking than the way in which the Tittabawassee on the one side and the Cass on the other come around Saginaw Bay to meet in Saginaw River.

The simplest and most natural form of drainage occurs where a smooth tilted plain is lifted above water level. There all the rain water can run straight to the lake, or allowing for minute undulations, gather into small streams which run parallel to each other down the slope. This simple type of drainage is almost perfectly and typically illustrated along the east side of the Thumb in Huron and Sanilac counties, and it may be seen in small areas elsewhere. I have noted in one section of Elmwood Township (T. 14 N., R. 10 E.) four distinct parallel water courses traversing diagonally a section of land a mile square.

It is obvious that the type of drainage produced by first opening the

higher lands to drainage is just the reverse. Hence it is subject to rearrangement. The Lower Peninsula of Michigan might, were it closely and accurately contoured, become a classical land for the study of the phenomena of stream capture. One can see it taking place even now. Ditches are found of which one end drains into one river valley, and the other end into another river valley (e. g., south of Bad Axe, T. 16 N., R. 12 E.), but little by little one stream will come to drain the ditch more than the other.

Instances of reversed drainage are therefore not uncommon. One instance, previously cited by students, is that the lower part of Dowagiac Creek has been reversed so that the St. Joseph now flows up it and to the lake that way, instead of south to Keokuk, as formerly. Another clear case is in Huron County, where the upper Willow occupies a valley once a Glacial outlet by way of the Cass to the south. In fact Shebeon, Pinnebog, and Pigeon rivers, especially the last, are encroaching on the Cass and will probably deprive it of the North Fork that comes down from Huron County. The Pigeon, using a Glacial channel to the Cass that it has reversed, has already effected an entrance into the main valley of the North Fork of the Cass. Man is assisting in this readjustment, for it is obviously to his interest to reclaim the rich lands of the swamps and the drained lakes along the shortest possible lines.

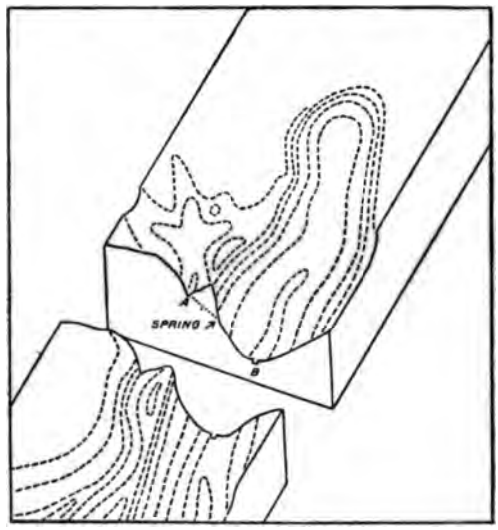

FIG. 7.—Diagram illustrating method of stream capture. A, dry channel; B, deeper encroaching channel with springs on its sides.

The streams which drained the ice front have many features that make them an easy prey to pirate streams. In the first place, flowing along the higher lands, with a circuitous course, they have easy grades, which weaken their power of erosion. In the second place, the ice streams, of which they are now deprived, carved valleys much too large for them and brought down much débris—more than the present streams can handle; and much of the débris was so coarse that there is a constant tendency for the water to percolate through the sand and gravel and do no erosive work whatever, except some little chemical erosion, which leaves the beds even more permeable than before. This is quite noticeable in the North Fork of the Cass, the bed of which

shows that re-erosive work is nearly at an end, for vegetation is pressing hard upon it. Now, as the vigorous headwaters of the pirate streams push into the plain of sand and gravel of such an old valley they naturally lower the water level, and the water of the valley is drained away by seepage through the sand and gravel. The annexed figure (fig. 7) is an ideal illustration of lateral seepage from an actual case; fig. 8 is also instructive. In fig. 7 the valleys are nearly parallel. In fig. 8 the attacking stream is working in at right angles to the ancient valley course. In many parts of the State one will come across valleys where, judging from the vegetation, there is now rarely any surface-water erosion, as the water sinks in and is absorbed by the sands and gravels (e. g., sec. 34, T. 24 N., R. 2 E.).

In some parts of the region of overwash sand and gravel kame plains (e. g., around Harrison, T. 19 N., R. 4 W., and Grayling, T. 26 N., R. 4 W.) one may have to sink 100 feet or more in surficial deposits before reaching water, and may then reach a real surface seepage water, while even the deep valleys are dry most of the year, so perfect is the subsurface drainage.

LAKES OF LOWER MICHIGAN.

The lakes of Michigan are numerous. Estimates of their number vary from five to fifteen thousand. There are twenty-five in the township of Grattan (T. 8 N., R. 9 W.) alone. They are of great importance as direct sources of water supply, as reservoirs which tend to steady the stream flow, and, finally, when they disappear, as furnishing the black muck soil with a shell-marl subsoil, that has proved wonderfully adapted to celery and other culture. The accompanying illustration, Pl. III, B, shows a field of onions on such land. It is the second type of lake—the shallow lake of the interlobate drainage—which is especially likely to be thus filled. The remarks concerning the lakes of the Kalamazoo River Basin, page 24, apply very nearly to any other part of the Lower Peninsula above the line of the old lake extensions, colored blue on Pl. II.

The following description has been taken from an unprinted paper, by Prof. C. A. Davis, read before the botanical section, Michigan Academy of Sciences, giving a graphic description of these pools:

"The lakes of the State, exclusive of the Great Lakes, cover an area of 1,225 square miles, or more than 784,000 acres, or about $\frac{1}{135}$ of the total area of the State, and they are so distributed that there is hardly a botanist in Michigan who can not readily reach one or more of them.

"The small lakes, particularly those of the Lower Peninsula, are commonly depressions in the drift, shallow and not of large extent, frequently partially filled in around the margin with the remains of former generations of plants, so that many of the typical features of lakes of hilly or mountainous regions are partly suppressed or entirely wanting. These lakes belong to recent geological time, and this undoubtedly accounts for some of their peculiarities. By far the

larger number of them exhibit the following features. A small sheet of water, roughly elliptical in shape, bordered by a marshy area of varying width, or on two or more sides by low, abruptly sloping, sandy, or gravelly hills. The marshy tract is frequently wider on the south than on the north side, and its character varies from a quaking bog at the inner margin through a sphagnous zone into a swamp, in which the prevailing trees may be tamarack, cedar, or spruce. The plants of the sphagnum zone are characteristically those of the boreal-life one, and in such lake margins we find northern plants reaching their outhern limits. The quaking bog is usually a lakeward extension of he shore plants and is a closely woven turf of the roots and root-ocks of various species of *Carex*, *Cyperus*, grasses, and at its outer argin consists sometimes of *Typha latifolium* and *Sparganium eury-rpum*. In the larger lakes the marshy border may not extend tirely around the margin, but it is usually noticeable along the uthern shore, where it may be of considerable extent, while the rest the shore is entirely without it."

Most of the lakes of Michigan belong, in origin, to the two classes eady described, i. e., they are either inclosed between moraine lges or are left as pools in the kame plains of sand and gravel. kes of these two classes are usually more than 750 feet above tide. general, the regions of numerous lakes are the regions of crowded raine belts, and they may be approximately traced in this way. t there are two or three other classes of lakes that deserve mention. First, there is a class of lakes which arise from the erosion of lime-ne into caves that finally tumble in and produce sink holes. ough there are some indications of sink holes in the Carboniferous estones, lakes of the sink-hole class are, so far as known, practi-lly confined to the lower Devonian limestones (Traverse and Dun-e) and occur only in the extreme southeast (Ottawa Lake, T. 8 S., 6 E.) and northeast (e. g., sec. 32, T. 33 N., R. 6 E.) of the State.

Second, there is a class of lakes which may be in part in rock or raine basins, but which owe their distinct existence to the fact that e Great Lakes now, or at a higher stage of water, have built sand rs across the mouth of long bays and have thus cut them off from e main body of water. Such lakes are frequently less than 25 feet ove the water level. A good illustration is the lake to the right in e view of Sleeping Bear Point (Pl. V), or Pine Lake, near Charle-ix, which is now reconnected by an artificial channel with Lake ichigan (T. 34 N., R. 8 W.), and it is easy to see, from the map or m Pl. IV, that Grand Traverse Bay might be converted into such lake.

Some of the lakes are nothing more than old river valleys flooded the tilting of the earth's crust and the consequent encroachment of e lake on the land. This is a class not clearly separate from the hers. Such lakes occur by the score along the west coast of Michi-n from Kalamazoo River to Frankfort, and seem to be submerged

river valleys,[1] but the bars built across their mouths, are as in the second class.

If, as Professor Gilbert has said, the land is rising to the northeast at the rate of 5 inches a century for each 100 miles, it is easy to see that such a stream as Saginaw River will also tend to be ponded back; and, in fact, so far as current is concerned, Saginaw River is now but a long, narrow lake.

When the ice lobes retired so that the heights of the rock surface lay in front of them, crowned by a heavy moraine, the water gathered in front of them in great lakes. The débris brought by streams in the ice was, in this case, laid down more smoothly and stratified with the clay that accompanied it. Thus the topography of these moraines laid down under water is far more gentle than that of the earlier ridges. On the east side the lake in front of the Huron-Erie lobe, as shown by Gilbert in the Ohio reports, drained off past Fort Wayne into the Maumee, and the waters of this lake level were about 220 feet above Lake Erie or 785 feet above tide level. Toward the north the beach lines are at a somewhat higher level, the change to water-laid topography occurring somewhere about 800 feet above tide.

In the center of the State a lake was penned up in the Saginaw Valley, as recognized by Winchell and Mudge, and flowed down Grand River. The highest water of this lake, as seen in the sandy gravels around Alma and Pompeii, seems to have been about 760 feet above tide, so that, as the swamps south of Ashley are about 85 feet above Lakes Michigan and Huron (i. e., 667 above tide), the water would have stood about 100 feet deep in the channel, unless it has gradually scoured it down to present level. It is no wonder, then, that the drift was scoured down to the rock at Grand Rapids and Ionia. It flowed into the lake which had been similarly formed in the lower end of Lake Michigan and was draining over into the Mississippi by the recently reopened Chicago outlet. This lake was at first at least 90 to 100 feet above the present lake level, or 680 feet above tide, and probably more.

As the ice retired the lake east found a number of drainage channels across the Thumb through Sanilac and Huron counties, as indicated in Pl. II.[2] Finally free communication was opened around the Thumb in Huron County. This produced a slight but preceptible drop in the water level of the eastern lake, but thereafter it remained relatively permanent, and is marked by a well-defined gravel line, not perfectly horizontal but rising a little to the north. This may be explained by the removal of the attraction of the ice mass to the north, or by a subsequent tilting. Around Ypsilanti (T. 3 S., R. 7 E.) it is 750 feet above tide, while in Iosco County (sec. 30, T. 22 N., R. 6 E.) it is about 775 feet above tide, and in Huron County, north of Verona (T. 16 N., R. 13 E.), it is about 774 feet above tide.

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[1] *See article* by Winchell in Harper's Magazine, Vol. XLIII, July, 1871, pp. 284 and 285.

[2] *See also article* by F. B. Taylor, Bull. Geol. Soc. Am., Vol. VIII, 1896, p. 31.

DUTCH POINT SAND SPIT, GRAND TRAVERSE BAY.

lake clays, and in slightly less degree to bowlder clays or till, known among drillers as "hardpan." Regions of this type are mainly included in the sections colored blue and light buff on the map (Pl. II).

2. Sandy regions will at some depth yield a supply of water. But a distinction must be made between the sandy belts of the lake-washed region, in which the sand and gravel are a very dry, superficial coating to the clay beneath, liable to contamination and likely to fail altogether in dry seasons like 1895, and the heavier sand and gravel regions, which represent drainage from the ice sheet, such as the great gravel plains of the Muskegon, the Manistee, and the well-named Au Sable. In such plains water is found at considerable, often at great, depths, but the supply once reached is abundant. The heavy sand regions are mainly colored brown and crosshatched on the map (Pl. II).

3. The alternate advances and retreats, whether of ice or of lake, have tended to produce an alternation of deposits more or less clayey.

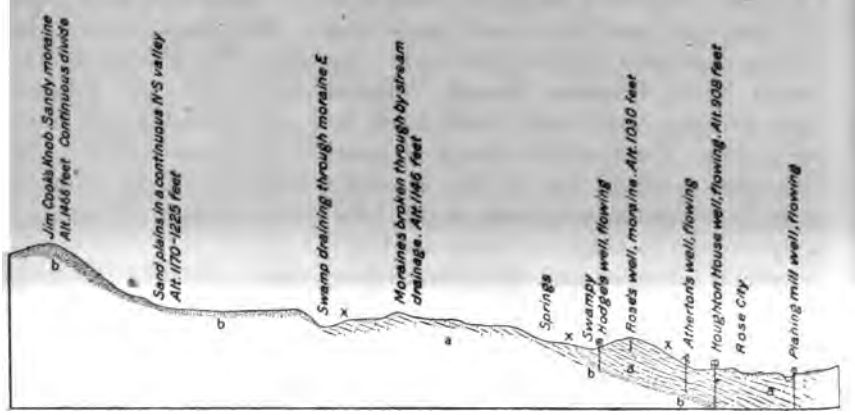

FIG. 8.—Profile near Rose City, Michigan. a, impervious beds—clayey till; b, pervious beds—sand and gravel; x, springs. Horizontal scale, 1 mile=1 inch; vertical scale, 400 feet=1 inch.

It is easy to see that in the case of a lake such deposits will dip slightly from the lake margin toward the lower, deeper parts of the lake bottom. But the same thing is true also of ice. The ice front would retire from the highlands, leaving an apron of gravel in front, and then a little change of climate would produce a readvance, in which it would roll up the apron ahead of it or roll over it and deposit a gravel clay (ground moraine) upon it. Or, if it retired so far as to leave a lake between it and its past position, it might push the lake clays on top of the shore gravels of this lake. That is in many cases what has occurred. In some cases, of course, the pervious bed is entirely destroyed; but often the pervious bed remains as a good source of water, and has head enough to produce a flow. Close to the lake-ward side of prominent moraines, shown upon the map (Pl. II), flows from the drift may be expected. The cross section near Rose City (fig. 8) illustrates this principle. In the midst of moraine regions

there is confused and broken topography, springs are common, and there are often small groups of flowing wells in the low grounds.

4. The ice was very likely to leave some gravel in all sheltered, i. e., southern sloping, parts of the rock surface or the valleys therein. If the rock itself was not impervious there was some circulation of water along it which leached out channels. Thus it is the rule, though not without exceptions, that just above the rock surface there is a water-bearing stratum.

METHODS OF SINKING WELLS.

While the wells in the rock have been almost invariably drilled, there has been considerable variety in the method of putting down wells in the drift, and a brief recapitulation may be suggestive.

First, of course, are the dug wells. Where experience has shown that many bowlders and stones are likely to be encountered, digging will probably prove the most economical method. Wells are dug 2 feet or more in diameter, and are variously cased. From all parts of the State come complaints that wooden casing soon rots and makes the water foul, and is almost always used longer than it ought to be.

Another form of casing is stoning, where stones are plenty. The disadvantage of stoning is, however, that it does not keep out the surface waters.

Where stone is scarce brick casing is often used, also large crocks, or sewer pipe about 2 feet in diameter. Properly sealed against surface water, these make excellent casings, though fragile and likely to be cracked by uneven settling of the earth.

A plan followed in some extra deep drift wells and worthy of wider adoption, is the use of a boiler plate shield and the cementing of the well as it is dug. Mr. E. R. Phillips has his well in Bay City cemented down to its bottom and a bed of charcoal and clean sand therein—an excellent plan for those who must use wells in unsatisfactory localities.

The disadvantage of combining a dug basin with some other form of well, and the various disadvantages of a lack of thorough casing are described on page 72.

Another kind of well is the driven well. This is a great favorite in the sandy and gravelly districts of the areas covered by Glacial drainage deposits (colored brown and crosshatched on the map, Pl. II). In the heavy clays of the lake clay areas (colored blue on the same map) it is quite common to use an earth auger and bore down, and this may be combined with driving where necessary.

The chief difficulties encountered are stones too large to be pushed aside, which have to be dynamited, quicksand, and fine sand, like that of an hourglass, which runs in faster than it can be pumped out. In going through strata carrying quicksand, work should be continued night and day without interruption. I do not know that artificially freezing or cementing the quicksand bed has ever been tried in

he State, though it would be effective. It would seem that especially n case of quicksand, a mode of sinking wells illustrated by Pl. III, 1, might prove very effective. This method consists of forcing down, n a smaller pipe within the casing, a current of water, under a very trong head (sometimes steam is also used), which scours out the soils nd lets the casing drop as it is tapped. There is thus no opportunity or the sand beyond the reach of the very strong current to pile in. 'hese quicksand beds sometimes contain water, but the well becomes asily clogged if its point is near quicksand.

EASTERN SHORE DISTRICT.

For the purpose of detailed description the State may be divided nto seven sections.[1]

In the eastern shore district is included nearly all the country which lopes off to the east from the land water-laid moraines along the eastrn part of Huron County down to Monroe. The surface soil is preominantly clay. This is varied by strips of sand along the streams, omposed of successive deltas and old shore lines more or less parallel o the lake,[2] along which the ridge roads often run. On the clay no urface wells can be obtained and deep wells prevail. On the sand idges shallow surface wells can be obtained, but are likely to fail in ry times and are, besides, at all times liable to pollution. In boring own an impervious lake clay or a gravelly clay, generally known as ardpan, is found. Interlaminated streaks of gravel are few and not uniform, except that generally just above bed rock there is a porous water-bearing seam. In the extreme south of this district through Monroe County, from Ottawa Lake to Sibleys (an area colored red on the map, Pl. VI), limestone outcrops are found, and the drift is accordingly shallow, but in passing to the northwest there is very soon encountered about 80 feet or so of the blue and gravelly clay. Where this clay overlies the limestone sulphureted hydrogen, which may also spring from the decomposition of the sulphide of iron in the drift, is generally accumulated, and the deeper wells—the so-called sulphur springs—are heavily charged with it. Where black shale underlies—and there is black shale both above and below the Berea grit—burning gas is very likely to accumulate, and often excites surprising hopes. Most of the deeper wells in Wayne are charged with one or the other of these two gases, but no large permanent supply can be expected from them, though in many cases they might for a time furnish a house or two with a convenient fuel. Flows of water from gravel beds are not uncommon throughout this region, and the number and strength of flows increase from the shore back toward the moraine.

[1] After making these sections I noted that there was a striking parallelism between the regions into which I had divided the State and those into which Professor Wheeler had divided it for study of floral distribution.

[2] In Huron County the markedly sandy strips are 20 to 25, 68, 98 to 118, and 163 to 193 feet above the lake.

ıere, too, the section of the drift becomes less monotonous, and there e more interlaminated gravels. At about 750 feet above tide, on e border of the moraine, on a line along through Britton, York, ilan, Ypsilanti, Northville, Birmingham, and Rochester to North reet, back of Port Huron, one may be reasonably sure of striking ıter which will rise nearly if not quite to the surface of the ground ıd frequently overflow. The water of these wells—e. g., that of the psilanti waterworks—is of excellent quality. Farther down the ope the drift beds are less porous and the water, if obtained, is kely to be too highly charged with gas and mineral for comfort.

Through this district, therefore, the sources of water supply may ɔ summarized as follows:

(1) Lakes. Only the Great Lakes are of practical importance and ·e the only satisfactory supply for large towns.

(2) Surface wells. The wells are generally very shallow and exhaustıle. Wells from gravel or sand "pockets" in the clay are very ncertain, but are likely to flow for a time. The Pagoda spring of ount Clemens appears to belong to this class, but yields more ·eely than is usually the case. Toward the upper margin of the istrict the supply is more abundant.

(3) Wells from base of drift. These are almost always present; the ıpply is ample and the flow probable. They are free from contamiation, and are somewhat highly mineralized, but probably not to a egree to render them useless.

SAGINAW VALLEY DISTRICT.

In this district is included the drainage of Saginaw River and part f the surface drainage—about to the 750-foot line and including the art once covered by Lake Saginaw. The rock surface is exceedıgly variable. The old coal measure plateau was cut up by gorges 00 to over 200 feet deep, which are more extensive than can be hown on the map (Pl. VI). But the present surface is flat and is aried only by the valleys which the larger streams have cut from 10 ɔ 30 feet below the plain. First with moraine till, and then with he lake clays, the rough rock surface has been plastered nearly mooth. Thus the depth of surface deposits is not uniform, varying rom even 0 to 500 feet, but being generally about 80 to 100 feet. 'inally, sand ridges frequently occur about 25 feet above the lake, hen again, as near Hemlock City, about 70 feet above the lake (655 bove tide), and again about 160 feet above the lake (742 to 766 feet bove tide), as at Alma, ıthaca, Gagetown, and Cass City.

These sand ridges yield surface water, easily exhausted and liable ɔ contamination. On the clay lands between them the farmers have ɔ go deeper for water, and rarely fail to find it. In most places there re beds of quicksand, which yield water under the clay and very ften gravel. Waters from these horizons always rise well, and in

many places flow, especially near the 700-foot contour. The quicksand wells, however, easily clog up and are short lived. The quality of the water is not so unexceptionable as the quantity. It is generally hard and not infrequently somewhat mineralized. But throughout all this region as good water, with as good or better head, can usually be obtained from underlying sandstones.

To the southeast in this district the drift coating is very thin, from 0 to 40 feet, and outcrops in the streams occur; but toward the west the coating becomes thicker. Thus, at St. Johns it is 141 feet deep; at Midland, 198 to 300 feet; at Mount Pleasant, 250 to 350; at Coleman, 300; and the greatest known depth of drift in this district lies at Alma, 495 feet. To the northwest in this region it will be exceptional cases and exploration for other things than water which will lead wells to rock. Especially is this true since ample supplies of flowing water can generally be obtained from the quicksands, which are very difficult to drill through. It will be noted, moreover, that this part of the region lies in a southwest direction from the gypsum quarries of Alabaster. This is the direction of Glacial motion. Hence it is not surprising to find gypsum disseminated through the drift. Prof. C. A. Davis has called attention to a bowlder of gypsum as large as two fists, which he discovered near Alma. This is certainly exceptional, and is of interest as showing the recent date of ice movement. A certain amount of gypsum is disseminated through the drift in this region and gets into the water. This is most marked at Mount Pleasant and in the region immediately around, as at Leaton. Here the wells in the drift, whether deep or shallow, are, without exception, permanently hard and highly impregnated with sulphate of lime. These mineral waters, though free from bacterial contamination and not likely to produce typhoid and diphtheria, are said to be injurious to the bowels and bladder of certain constitutions, while they might be what others need. Persons in this region who tend to a uric acid diathesis might find filtered rain water better than patent medicines. A trace of common salt, or lithium carbonate or sodic sulphate, might be added to remove the flat taste of the water.

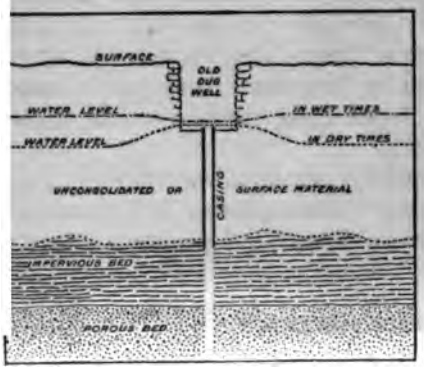

FIG. 9.—Diagram illustrating evils of insufficient casing.

This district is much like the first except that gas is not common in the wells. The wells in surface sands are usually shallow and easily exhausted in dry times. Deeper wells in quicksand or gravel in or under the clay can generally be obtained, but the water is often very

hard. The thickness of drift—i. e., depth to bed rock—is quite irregular, but is much greater to the northwest.

One practice common in this district but not confined to it, which can not be too strongly deprecated, is drilling from a basin or dug well and letting the water resulting flow directly into the basin, the upper basin remaining as pervious as ever. The way in which this practice arises is simple and natural. A farmer begins by a dug well, perhaps 16 feet down in the surface sands, as in fig. 9. In a dry season like that of 1895 his well goes dry. He borrows an augur and bores down through sand and then through the clay, say 20 feet more, and strikes another porous bed full of water under a good head, which rises and fills his well up far enough, and he stops satisfied. But in the first place the impervious clays through which he has bored will probably creep in and fill the hole, and in a few years the work will have to be repeated. In the second place, suppose that the well is cased from the bottom, or that the flow from the lower pervious beds is so strong as to keep the hole open; in dry times the water from the lower bed will still work out sidewise through the stone curbing into the upper beds that have gone dry. Thus the head of the lower beds will be wasted, and some neighbor who has had a flowing well from that bed may suddenly find his flow stopped, while he himself will have to exert himself more than should be necessary in operating the pump. Again, if there is a strong flow upward from the lower beds, sand may be carried up in sufficient quantities to fill the upper well and leave a cavity around the bottom of the hole through the impervious beds, into which they will finally fall and seal the well, even though the beds themselves are cased. Finally, there is nothing to prevent a rainy season from reversing the process—raising the water level in the upper beds, changing the current, and contaminating the supply with rain water and surface drainage, so that the certainty of purity, which might easily be obtained, is lost.

If, however, as shown by the dotted lines, the hole is cased and the casing continued to the surface, the head of the lower bed will be preserved, risk of contamination removed, and the life of the well lengthened.

NORTHEASTERN SHORE DISTRICT.

This district is occupied mainly by the drainage valley of Thunder Bay River, with the lower reaches of the streams which drain into Huron Bay between it and the Tittabawassee, and the streams, mostly small and insignificant, which lie to the north of Thunder Bay River.

To the southwest of this district lies the high interior moraine which surrounds the Muskegon, marks most sharply the outline of the Michigan-Saginaw cusp, and probably includes the highest points of the peninsula (e. g., 1,465 feet, at Jim Cook's knob, on the north line of sec. 34, T. 24 N., R. 2 E., and, it is said, 1,682 feet near Otsego). Near West Branch the district [illegible]ches nearest the waters of the

lake, and there and at Wolverine the descent, from over 1,200 feet to less than 700 feet, is very abrupt, especially in the stream valleys. This region is but newly settled and is still in large part wilderness.

The general character of the district is somewhat as follows: Around the nucleus (the central district) of sand plains, about 1,180 feet above tide, except as cut by river valleys, runs a moraine, which is mainly or at times entirely covered with sand and frequently rises over 1,400 feet above tide. (See fig. 8.) There is also another sand plain, about as high as the inner sand plain but narrower, and then a moraine, only about 1,200 feet above tide, which is clayey and clothed with hard wood, especially on its northerly or easterly side. Then the moraine is deeply gullied, and there is a rapid drop to about 960 feet above tide, where there are again extensive sand plains. Inclosing these is another broken clayey morainal belt frequently 1,000 feet above tide, and then another drop brings us to about 800 feet above tide. Below this the moraines are less marked, and gravel ridges, produced as shore beaches, replace the extensive overwash sand plains of the higher regions, studded with jack pine. The soil becomes clay with streaks of sand, rather than sand interrupted by lines of clay hills. In other words, there is a series of encircling moraines as shown on Pl. II, and between each moraine and the one next within the valley the space has been filled with sand, shown in brown and crosshatched, nearly to the level of the outer moraine, and often covering it heavily. In the sandy regions water may be obtained from surface sand, though it may be quite deep. Whenever streams like the Au Sable or Au Gres have cut down through the sands to underlying clays springs occur, and they are abundant in this region.

The drift through all this region is probably deep, and the clay moraines probably mark epochs of readvance of the ice, when it was likely to override the sand deposits formed in front of it in its retreat. In the few deep wells already sunk deposits of sand and gravel are found under the clay and till. Wells sunk into them, especially near the moraine belts on the north and east sides, may be expected to find plenty of water with considerable head. Fig. 8, from conditions at Rose City, will show how favorable are the conditions for artesian wells. There are high, sandy gathering grounds on the side south or west of the moraine, and higher semi-impervious ground with higher water level between the gathering ground and the discharge.[1] Flowing wells may be expected, therefore, all along from West Branch past Rose City to Indian River.

On the moraine belts the same sheets of water-bearing gravel may be struck, but the height to which the water will rise in the well depends on the altitude.

On the sand plains to the southwest of a moraine belt it will be necessary, except in low spots, to go deep for even surface water. There

[1] Requisite and qualifying conditions of artesian wells, by T. C. Chamberlin: Fifth Ann. Rept. *U. S. Geol. Survey*, 1885, pp. 131 to 172.

are a great many fine, undeveloped water powers in this region, and lakes are quite numerous. The quality of the water is generally excellent. It is, of course, hard, and it has been stated that 80 per cent of horse diseases are due to hard water. The water is not suited to boiler use. But the hard water of this region probably differs from that of Saginaw Valley and around Mount Pleasant, in that its hardness is largely temporary, as letting the water stand removes some, and boiling or breaking with quicklime all, of the hardness, which consists of lime and iron.

On the other side of Thunder Bay River a smooth moraine, which covers an underlying limestone ridge, gently rises. The coating of drift is shallow, the underlying limestones are pervious, and it is often necessary to go down into rock to obtain a permanent water supply.

Throughout this district there are many ponds. In some the water is said to be quite soft. The ponds are either clay moraine tarns, crooked lakes left in abandoned channels of the old ice drainage, or sometimes sink holes and valleys in the limestone. At present their main worth is to the hunter, the fisherman, and the lumberman, but the time may come when they will be useful as reservoirs for mill streams or as town water supplies. In most of this district good water supplies can also be obtained from the rock, though at considerable depths.

WESTERN SHORE DISTRICT.

There is much greater difficulty in defining, by natural characteristics, this district than some of the previous ones. There is a series of moraines which come diagonally down toward Lake Michigan (see Pl. V), becoming gradually lower, more extended, and more undulating in contour. The moraines are heavily swathed in gravels, sands, and clays of the valley trains which lie between them. At the extreme north of this district, from Bay View and Petoskey southwest, there is a rock ridge, and there is probably also a rock ridge from Grand Rapids northwest into Oceana County, where the drift covering is comparatively thin. Between these ridges the drift is very thick, so that only the deep salt or mineral wells strike rock, which is encountered 500 or 600 feet down. Probably the relief of the rock surface is considerable. This thick layer of drift is generally varied in section, as the wells at Big Rapids, Traverse City, etc., show, and various sands and gravels yield water; and on lower grounds, as at Traverse City, at the Nochemo springs (really wells), near Reed City, around Empire and White Cloud, and at Mecosta, flows are likely to occur. The level of the flows at these places is below that in the adjacent country, but on the higher grounds, as about Walton, especially on the great sand and gravel plains which are so pronounced a feature, it is often necessary to go 100 feet or more to reach water. Usually, however, water can be reached by a drive well, and of course water at such depths is steadier in supply and freer from some forms of contamination.

BARRIER BEACH CONNECTING EMPIRE BLUFFS AND SLEEPING BEAR POINT, LAKE MICHIGAN.

makes a great difference in the cost of drilling. While for 2-inch holes in the softer strata (the coal measures or Coldwater shales) 50 cents a foot has been a standard rate and will yield good wages if there is no special difficulty encountered, some specially hard layer of a foot may take more time than all the rest of the well; and in general through the State wells have cost about $1 a foot. Usually half the time at least in drilling a well is consumed in overcoming exceptional difficulties and in making repairs.

In mere churn drillings coal is difficult to distinguish from black shale, at least to determine its exact thickness; though an expert, by turning the drill 90 degrees each time and thus getting larger pieces, and by noting especially the peculiar crunch under the drill, which may be felt if the hand is on the rope, may ascertain approximately the nature and thickness of a deposit. Gypsum or plaster is another substance which is often not recognized, and which it is highly important to avoid if good drinking water is desired.

Usually, just before striking through shale into a strong stream of water with a good head, a certain springiness of the churn drill is noticed by the driller, which warns him that some new development may soon be expected, and it is common to find a red layer or a hard cap (specially charged with pyrite) or crust just before piercing a stratum containing salt water. Is not the sulphur of the ferrous sulphide of the hard cap, or the ferric oxide of the red shales derived from the sulphates of the brine?

A description of the rock series, not primarily from the view of the paleontologist or general geologist but from that of the seeker after water—fresh, medicinal, or salt—follows.

CARBONIFEROUS FORMATION.

JACKSON COAL MEASURES TO MARSHALL SANDSTONE.

The central part of the State, as shown by the map, Pl. VI, and by the cross section, fig. 10, is occupied by a series of rocks belonging to the Carboniferous formation, in some respects not unlike the coal measures of Ohio and Indiana, with some beds that can be closely paralleled with those coal measures and yet with such marked points of difference as to render it probable that for most of the time, at any rate, there was little or no continuous connection with any other State, but that the rocks were laid down in an inland sea, between Canadian highlands on the north and flat reaches of the emerging continent on the south. At the base of the series is a heavy white sandstone—the Napoleon or Upper Marshall—which is very massive and thick to the east and southeast, as shown in fig. 12, but becomes somewhat thinner toward the north, although it is rarely less than 50 feet of well-defined water-bearing sandstone. It lies directly under the drift, as the map shows, through most of the broad belt of higher land that extends from the Thumb down to Hillsdale County. It is a

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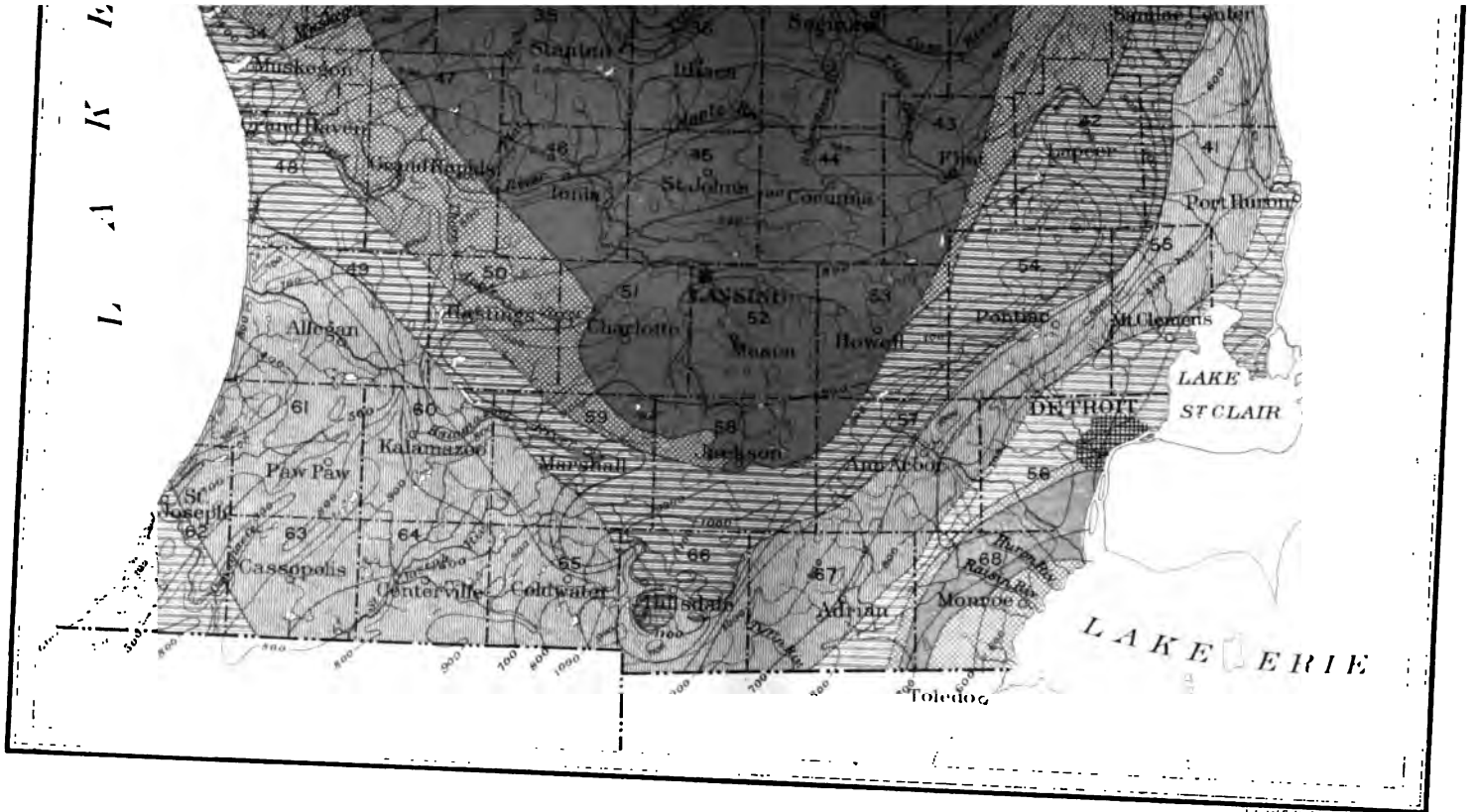
GEOLOGICAL FORMATIONS
OF THE
LOWER PENINSULA OF MICHIGAN
REVISED FROM MAP IN VOL V OF THE STATE REPORTS
BY ALFRED C. LANE.
1898.
LEGEND
APPROXIMATE EQUIVALENT
LOCAL NAME
Coal measures
Kaskaskia Keokuk
Kinderhook
Waverly and Cuyahoga
Ohio and black shale
Hamilton
Upper Helderberg
Lower Helderberg
Jackson series
Parma sandstone and Michigan series
Marshall series
Coldwater shales
Saint Clair shales
Traverse
Dundee limestone
Monroe above Sylvania sandstone
Monroe below Sylvania sandstone
Contours of rock surface above sea level
Scale of miles
0 10 20 30 40 50
1898
Mackinaw
St. Ignace
STRAITS OF MACKINAC
Cheboygan
Harbor Springs
Rogers
Charlevoix
Alpena
Atlanta
Bellaire
Gaylord
Leland
Traverse City
Kalkaska
Harrisville
Grayling
Roscommon
Lake City
Cadillac
Manistee
Pinconning
MICHIGAN
MANITOU IS
BAY


LAKE
Muskegon
Grand Haven
Grand Rapids
Ionia
Stanton
Ithaca
St. Johns
Corunna
Sagina
Flint
Lapeer
Sandusky
Port Huron
Allegan
Hastings
Charlotte
LANSING
Owosso
Howell
Pontiac
Mt. Clemens
LAKE
ST CLAIR
DETROIT
Kalamazoo
Paw Paw
Marshall
Jackson
Ann Arbor
St. Joseph
Cassopolis
Centerville
Coldwater
Hillsdale
Adrian
Monroe
Toledo
LAKE ERIE

rolific water bearer, yielding numerous flowing wells at a moderate epth (250 feet) throughout the west part of Huron County to Sebewaing. Under Tuscola county it continues, as at Fairgrove, though at 'eese it is getting a little too salt, and so along past Flint, Vassar, and irch Run, to Corunna, Lansing, and Mason. Along this line and south here is usually good water in this formation. There is frequently above his formation intensely salt or bitter waters, pierced on the way going own, which must be cased out. It seems that to the northwest an arm f the sea was cut off from the ocean, where evaporation exceeded preipitation, depositing the gypsum beds which extend from Alabaster nd Soule, in Huron County, to Grand Rapids, and saturating the rocks rith a very salt brine. This formation has no parallel in adjacent tates, and hence is known as the Michigan series. It consists of light-

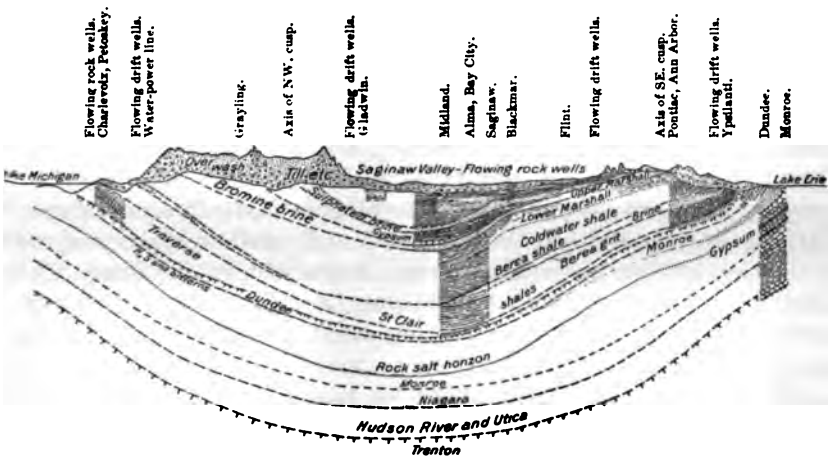


FIG. 10.—Cross section of the Lower Michigan Basin. Horizontal scale, 1 mile = .135 inch; vertical scale, 1,200 feet = .321 inch.

olored blue or gray shales, hydraulic limestones, and gypsum beds s extent to the southeast seems to be somewhat irregular, as it lies in ays and synclinals in the Marshall sandstone. It can be followed, ven where it does not outcrop, by its effect on the mineral waters.

In fact, in many parts of Lower Michigan, where outcrops of bed ock are scarce, important geologic data can thus be gathered. In uch of our work in Huron County, Professor Davis and I discarded ie familiar tools of the geologist, the hammer and the compass, nd instead carried a urinometer and a small leather case containing arium chloride ($BaCl_2$), for sulphate test, silver nitrate ($AgNO_3$), for hlorine test, ammonium oxalate—$(NH_4)_2C_2O_4$—for lime, and somemes tannic acid, for iron, and went from farm to farm inquiring ie depth to rock, etc., and testing the waters. The line between the 'pper Marshall or Napoleon and the Michigan series was traceable, narply within a mile, by the reaction for sulphates which the latter eries gave, and by a rapid increase in total mineral contents. This

purely objective line agreed with reports as to the nature of the rocks and the rare outcrops. (Compare Pl. VI and fig. 12.) For further details reference may be made to the forthcoming report of the State geological survey on Huron County.

It is not uncommon, however, to find good fresh water in the Marshall sandstones directly beneath the Michigan series; there seem to be two reasons why the salt water has not worked down and charged the Marshall sandstone.

In the first place, as the Marshall sandstone outcrops all around under the high land, there is a strong pressure, nearly if not quite enough to make the water in the center of the basins rise to the surface. Thus the tendency is for the water to work up rather than down in the lower central parts of the Michigan Basin, which are overlain by the Michigan series and by the outcrops. This tendency has been shown in hundreds of wells for fresh water and in dozens of wells for brine, which have been put down in the Saginaw Valley. The Marshall, toward the center, becomes deeper and more salt. It is the source of the brines of Saginaw and Bay City, of the brominiferous brine of Midland, St. Louis, and Alma, and probably of that of Big Rapids; it is almost saturated with salt. The salt, however, is not derived from above, since it is comparatively free from gypsum. At one time the wells in the Saginaw Valley made a really noticeable reduction in the percentage of salt contained in the brine. They may have drawn in fresh water from the sides to replace the brine extracted at the middle of the basin. The Marshall sandstone is generally easy drilling.

The overlying Michigan series from Bay Port to Saginaw, Midland, Alma, and Grand Rapids is a trifle over 200 feet thick. The position and thickness of the gypsum and hydraulic limestone beds, which are intercalated in the prevalent series of gray or blue shales, are not constant. To a certain extent this appearance may be due merely to imperfect records. Some of the gypsum beds are quite extensive. To the southeast, even around Sebewaing, the gypsum feathers out. Of its character to the north little or nothing is known. Water from the Michigan series is generally scanty or strongly mineralized. Occasionally pyritiferous beds and cherty limestones make hard drilling.

A change of climate, or more likely a slight depression making an open sea, probably caused the deposition on top of the Michigan series of a series of cherty limestones and sandstones of an entirely different character from those of the Michigan series—almost exactly paralleled by the Maxville limestone of Ohio and rich in similar fossils. In this series I am now inclined to include not only the Grand Rapids limestone but Winchell's Parma sandstone. The sections and borings at Bay Port, at Charity Island, and elsewhere have convinced me that limestones and sandstones are intimately intercalated at this horizon. Many of the sandstones are highly cross bedded, and according to the observations of the writer are apparently mere sand

bars. This is noted in the drill cores of the Bay Port quarry explorations by Rominger, who called it an unconformity, also on Charity Island, and by Winchell in his original description of the Parma around Jackson. The Bay Port limestone has the strongest possible resemblance to the Grand Rapids limestone in character and in fossils, and both are intimately associated with and underlain by sandstones.

The brines of this horizon, as pointed out by Garrigues, run higher in sulphates of lime, etc., and lower in earthy chlorides than do those of the Marshall; this is in harmony with the general theory of the upward pressure of the waters of the basin. The Parma sandstone is not always recognizable as distinct from the Marshall, although to the north from Bay Port it can be fairly well traced to Sebewaing, Bay City, Midland, Alma, and as far as Ithaca to the southeast toward Corunna and Flint. As the Michigan series feathers out this Parma sandstone either feathers out also or merges in the great shore development of the Marshall sandstone. (See fig. 10.) I now think that the record of the Jackson well is misinterpreted.[1] The Parma and Marshall are both probably merged in the great sandstone from 83 to 373 feet below the surface, the dividing line being perhaps near 200 feet, while the blue sandstones at 415 and 660 feet are probably merely minor beds of the Lower Marshall or Coldwater, respectively—Cuyahoga formations, especially as they are not free water bearers.

Returning once more to the Parma horizon—that of the Grand Rapids and Bay Port limestones—the water is usually hard, but at Bay Port it is quite pure, and no doubt is the water horizon of many wells besides those at Ithaca, especially in the region about Mason, Lansing, Owosso, and Birch Run, where thus far it can hardly be separated from the Marshall. It has been but little used for brine.

Above the Parma comes a varied series of black shales, fire clays, black band iron ores, and coals and sandstones. The sandstones usually yield water, but the water is generally quite mineralized (being occasionally prescribed for the sick) and is sometimes a brackish water which cattle drink greedily. Wells in the coal measures generally have a good head, and frequently flow. The sandstones are generally white, except well up in the series, while to the northwest, around Ionia, Ashley, St. Johns, St. Louis, and in Garfield Township (T. 16 N., R. 3 E.) there are records of a red sandstone, which Winchell called the Woodville sandstone. This red sandstone also yields water which is rather strongly mineralized, but it is yet little known, and it can not be said how far the red color is due to surface oxidation. In some cases it appears too thick for that and reminds one of the upper barren coal measures of Ohio and West Virginia, and, as at Saginaw, it appears to be quite unconformable on the coal measures proper.

[1] Geol. Survey Michigan, Vol. V, Part II, 1895, Pl. XXIII.

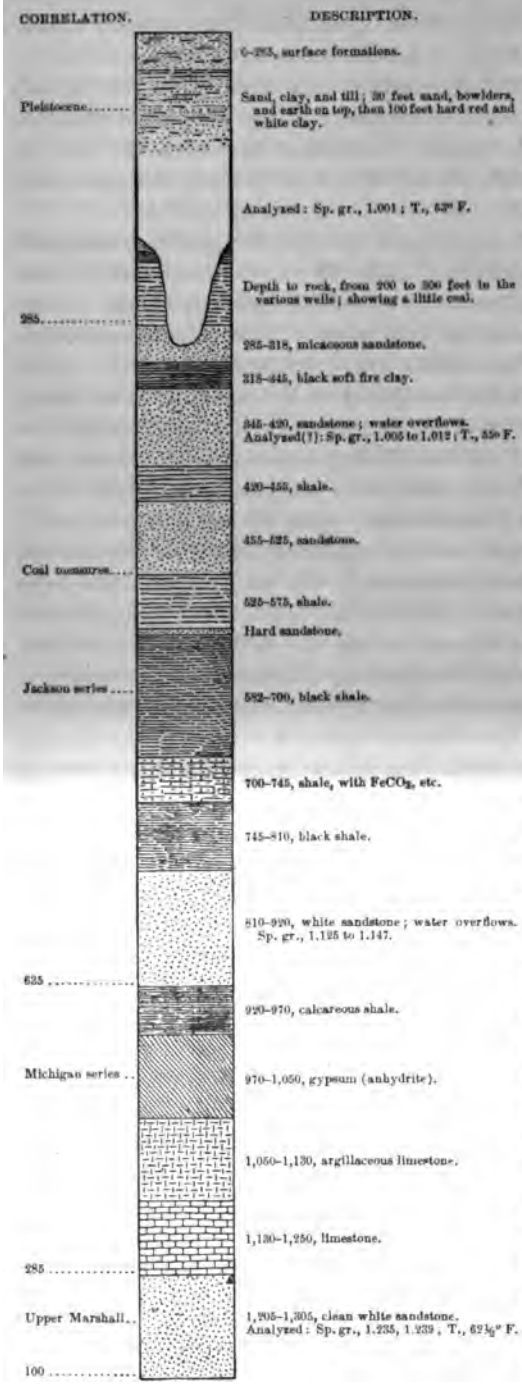


FIG. 11.—Section of well at Midland, Michigan. Altitude about 613 feet.

Above the Parma at Midland (see fig. 11), or combining the well records at St. Louis and Alma, there is a series of coal measures 400 to 600 feet thick, and sandstones are very abundant in the upper half, but are also very irregular—mere channels which will here cut entirely through a coal seam which a few feet away will be as strong as ever. One bore hole has found no coal, and 30 feet away one put down later for water passed through 3 feet of coal. These sandstone channels have been excellently exhibited in some of the Jackson coal mine plans by J. Holcroft.

This coal basin was deeply cut into by stream valleys before the ice swept over it and filled them. Hence the depth to rock is very uncertain and is more uncertain toward the northwest. The shore ridge of Marshall sandstone seems to have acted as a divide from which the streams flowed, gathering strength as they went. The abundance of deep wells in Huron County has rendered it possible to trace quite accurately in the rock contours of Pl. VI one valley which, coming down from Soule, is deflected by the Bay Port limestone and passes south through T. 16 N., R. 10 E., being about 140 feet deep, while on the general plateau

around the valley the depth of drift is less than 50 feet. Thence it passes 3 miles southeast of Sebewaing, then close to Unionville, and on west. There are irregularities in the depth of wells around West Saginaw and Bay City that indicate spurs of this valley, and the next well-marked location is at Midland, where some wells, like those near Hubbard to the north, find only about 200 feet of drift, while others, at the east end of the town, find 300 feet of drift. Wells are said to have struck rock at 76 feet in Mount Pleasant, but on the other hand wells north of there have gone 160 feet, wells west 355 feet, and wells south 205 feet without striking rock. At Alma it is 495 feet to rock, and at St. Louis, 3 miles away, it is only 355 feet or less, and at Ithaca 330 feet. At Big Rapids it is 600 feet to rock, while at Ludington, Manistee, and Frankfort, although close to the lake, there is a great depth of drift. These facts indicate clearly enough an incised valley system of 100-foot ravines, and also seem to indicate, contrary to Spencer's very natural hypothesis, followed by Mudge,[1] that the drainage of the coal basin was toward the west and not by Saginaw Bay, both because the depth of the ravine steadily increases, and also because the limestone ridge seems to run continuously across the mouth of Saginaw Bay, from the islands off Bay Port, in continuous rock bottom to Charity Island, and outcrops again on the north shore. The limestone may be followed near Omer and Prescott at a higher level than the bottom of the valley just described. The rock contours of Pl. VI illustrate these facts.

The troughs which Mr. Mudge assumes represent troughs or valleys in the rock surface are sufficiently explained by the Glacial drainage, which, indeed, Mr. Mudge has pointed out for the Ionia channel; and the very fact that in the Ionia channel the Grand River has in two distinct places struck bed rock far above the lower rock surface of the Saginaw Valley makes the supposition that it follows a rock channel rather forced. There are two other arguments of a general nature for my interpretation of the rock surface. In the first place, the rock ridge seems much more broken, the depth of drift far more irregular, and the topographic relief greater in the Grand Traverse region than in the Thumb of Michigan, which indicates that the former region is farther downstream, or nearer the master valley, than the latter. In the second place, the generally accepted theory of a greater northern elevation of the land preceding glaciation disproves the supposition that the gradient from Alma northeast was reversed, and makes the course of the valley from Bad Axe to Ithaca even more natural. From that point on its course is much less certain. It seems to have been deflected when it met the northwest-striking sandstones and limestones beneath the softer coal measures, at the southwest side of the coal basin.

[1] Am. Jour. Sci., 4th ser., Vol. IV, 1897, p. 384.

CARBONIFEROUS AND DEVONIAN SHALES.

LOWER MARSHALL SANDSTONE.

Beneath the heavy Upper Marshall sandstone which, as has already been mentioned, lines the shore of Huron County from Rush Lake to Hat Point, there are in Huron County (see fig. 12) about 260 feet of strata which are largely sandy flags and include three well-marked sandstones, one outcropping at Port Austin, another at Pointe Aux Barques, and another—the famous Huron blue stones, used for whetstones and grindstones throughout the United States. The series is very ferruginous, and beds often become red and friable as the iron oxidizes, although they are green or blue when fresh. These sandstones may be traced under cover by wells or by scattered outcrops through Huron County and into Sanilac County. Generally the supply of water is ample, the quality excellent (although occasionally salty streaks occur in the Lower Marshall), and occasionally, as near Bad Axe and Port Austin, in exceptionally low ground there are flows. As the sandstones are traced to the west under cover, they are soon lost, except when they merge into a belt of red rock, paint rock, red shale, sandy shale, etc., in which form they may be traced quite continuously as far at least as Saginaw River. They are evidently shore deposits of no wide range and have not yet been successfully followed individually to the southwest. They are transition beds from the Upper Marshall or Napoleon sandstone to the great shale formation below. They are easy to drill, and extend the width of the Marshall belt, from which good water can be obtained a rather indefinite distance to the southeast.

COLDWATER SHALES.

Farther down, in the Coldwater shales proper, the sandstone seams grow thinner and finer grained, and the water contained is more apt to be salty. Little sheets of sandstone cemented by carbonate of iron, as at Pointe Aux Barques light-house, at Sand Beach, and at Richmondville, are found at various levels in the Coldwater shales, but in general this formation is composed of fine-grained, micaceous, bluish shales, easily drilled and very dry. In Caseville, about 400 feet below the Upper Marshall, is a brine which seems to be fairly persistent and which is possibly even more marked to the northwest. In outcrop balls of carbonate of iron are frequent, and one wonders how often the bands of limestone recorded as encountered in drilling are nothing but such balls.

BEREA SHALE AND GRIT.

About 1,000 feet below the Upper Marshall the shales become blacker. The horizon of the Berea shale recognized in Ohio is reached, and then all along the southeastern part of the State the Berea grit is

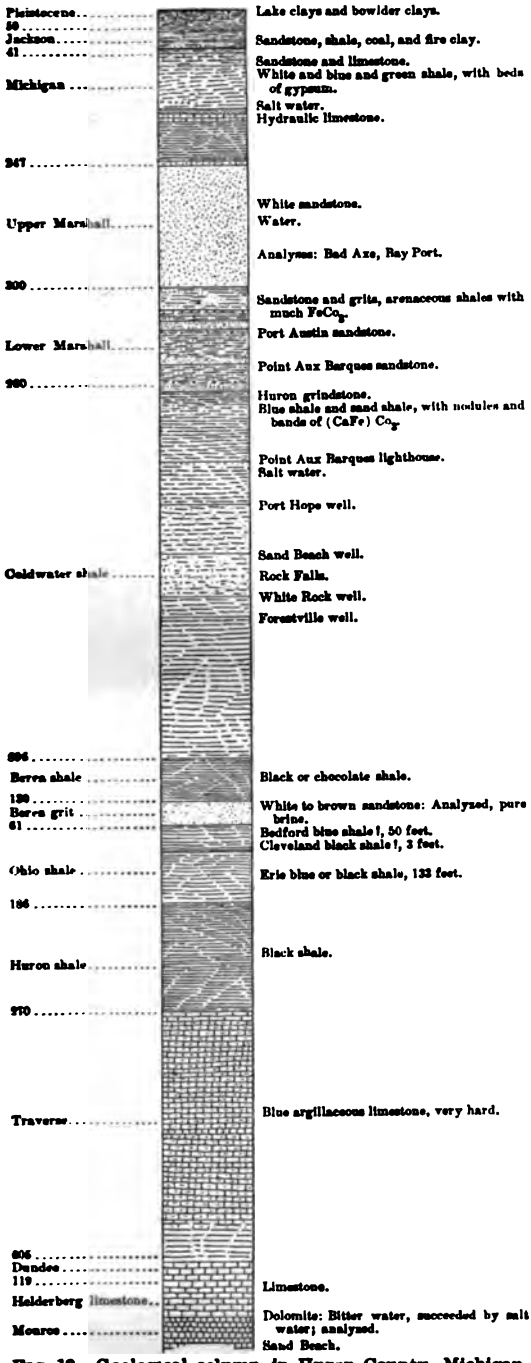


FIG. 12.—Geological column in Huron County, Michigan, adapted to the wells at Caseville and Sand Beach but illustrative also of those at Sebewaing, Bay Port, Port Crescent, Port Austin, Grindstone City, New River, Port Hope, White Rock, Forestville, etc.

well developed. It is a horizon well known for brine, and is followed to a depth of 1,650 to 1,750 feet at Caseville and at Blackmar, but is quite salt even when not very deep, as at Forestville, Ann Arbor, and Ypsilanti. At the latter place it seems to be more salt than underlying strata. It may be the source of some of the salt in wells about Ray (T. 4 N., R. 13 E.), Utica, Wales, and Rochester. With black shales above and below it is not surprising that the Berea grit frequently contains gas, and that many of the wells which strike gas immediately beneath the clays seem to be located over its beveled edge. It does not seem to be a marked topographic feature, nor does it break the general valley of the shales above and below. The Berea brines are of very good quality. Where recently struck in Bay City, at a depth of 2,200 feet, it actually flows, which, in a concentrated brine, indicates a considerable head.

ST. CLAIR BLACK SHALES.

Though the Bedford shales immediately below the Berea grit are often blue or red (oxidized blue), black soon becomes predominant, at

first in streaks (Cleveland shale), but later in a solid mass of 100 to 300 feet or more of bituminous shale nearly equivalent to the Ohio shale, a horizon widely marked and in a general way recognizable all over the State. This shale is somewhat sticky, but on the whole is easily drilled and is of importance as lying just above the horizons which contain most of the more famous bath waters of the State. From the Marshall down to the base of these black shales, with the possible exception of the Berea grit, there is no horizon of much importance either for brine or as a source of water, and in regions where these formations underlie the drift the prospects for rock wells for drinking water are not generally encouraging. Of course, near the outside margin good water may be obtained by drilling through to lower beds.

In general this great series of shales probably makes valleys lying between the Marshall sandstone ridge on one side and the ridge of the Dundee limestones on the other, and this is exhibited in the rock contours of Pl. VI and in the rock profile of fig. 10.

Very remarkable is the occurrence of a 6-foot bed of rock salt in this formation at Bay City, with black shale immediately above and below. This occurrence seems to show that the black shale is not a deep sea sargasso-like deposit.

LOWER DEVONIAN AND UPPER SILURIAN LIMESTONES.

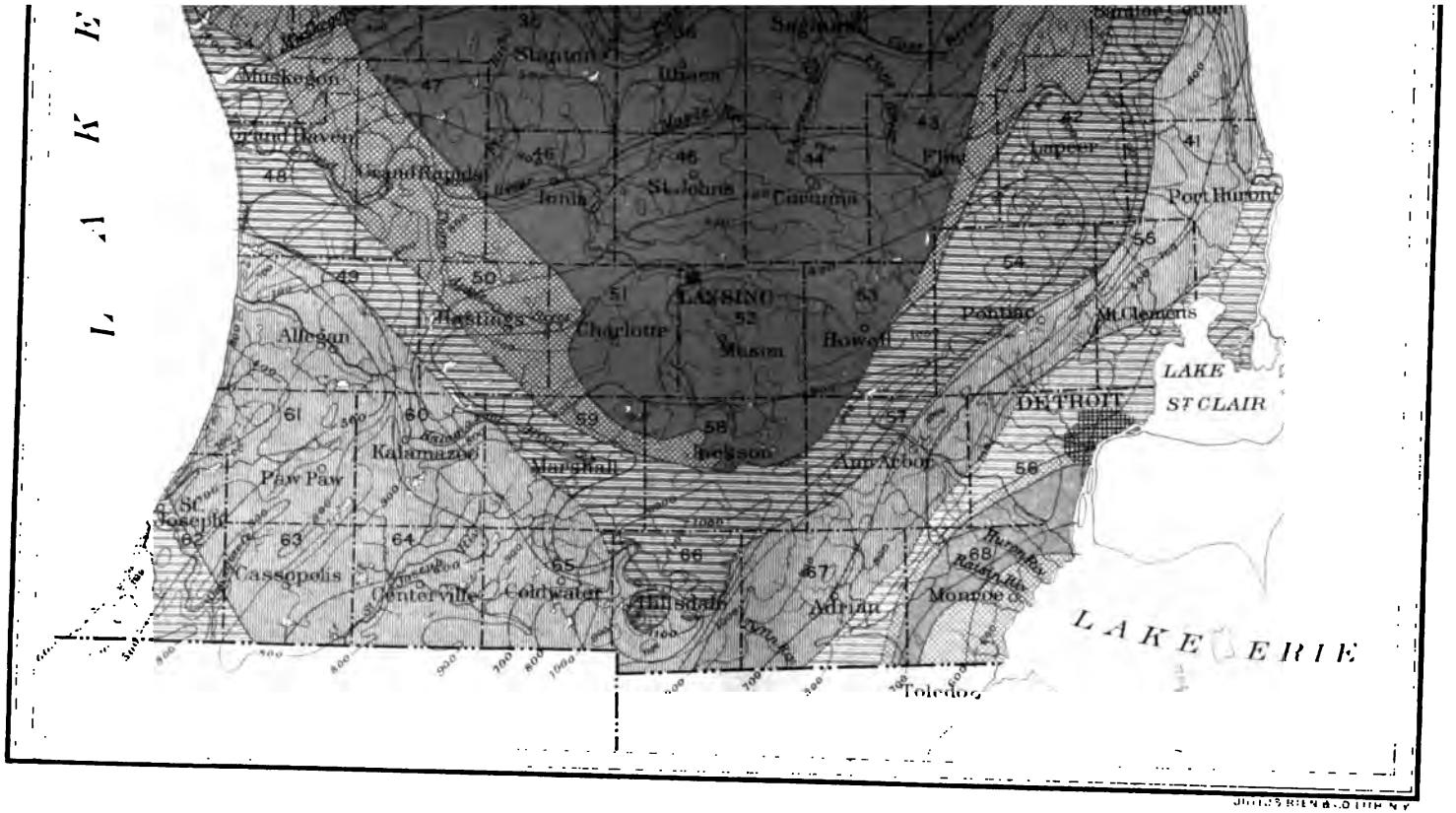
TRAVERSE SERIES (HAMILTON).

A transition series between the black shales above and the limestone series below is of slight importance in the south part of the State, where it is about 80 feet thick, but rapidly increases in thickness and in interest toward the north. Along the St. Clair River—at Port Huron, and elsewhere—it has thickened to over 300 feet and is subdivided as follows:

Typical section of series between St. Clair black shales and Dundee limestones.

	Feet.
Hard argillaceous limestone	2
Shale, argillaceous soapstone	12
Limestones, "top limestones," argillaceous, often containing gas	80
Shale, "top soapstone," argillaceous	150
Limestone, "middle limestone," argillaceous	4
Shale, "lower soapstone"	65

Beneath the last member are light-colored Dundee limestones, yielding gas and mineral water. The "middle limestone" is not always recognized, and the shales are calcareous, so that they may be considered alternations of calcareous shales and of argillaceous marls or limestones. The division into a top of limestone and a bottom of shale can be traced throughout the State. On the north side of the basin, from Alpena to Charlevoix and Frankfort, the formation is 500


LAKE
Muskegon
Grand Haven
Grand Rapids
Stanton
Ionia
St. Johns
Ithaca
Caledonia
Flint
Lapeer
Port Huron
Allegan
Hastings
Charlotte
LANSING
Mason
Howell
Pontiac
Mt. Clemens
LAKE ST CLAIR
DETROIT
Kalamazoo
Marshall
Jackson
Ann Arbor
Paw Paw
St. Joseph
Cassopolis
Centerville
Coldwater
Hillsdale
Adrian
Monroe
Toledo
LAKE ERIE

generally very light yellow in color, is full of flint, and is very hard, so that the drilling is slow at times. It effervesces very freely with acid, and some of the layers rank as the purest limestone of the State, containing 98 per cent of calcium carbonate ($CaCO_3$).

It is almost always more or less permeated with water which is charged with hydrogen sulphide (H_2S) even at Petoskey. When under greater cover the water becomes more salty, but is also strongly charged with other ingredients than salt—real bittern, or mother liquor—and is the most valued mineral water in Michigan.

The deposit of celestite with native sulphur has been associated by Professor Sherzer with the occurrence of traces of strontia (SrO) in these sulphureted waters. Frequently, also, oil or gas is encountered. In spite of the strength of this brine at times (at Charlotte the specific weight is 1.198) it is too impure for salt manufacture, and is mainly important medicinally.

The line between this formation and the one below, being one chiefly between limestone and dolomite, can be surely ascertained only by the use of acid. Hence over most of the State the line is still very uncertain.

THE MONROE AND SALINA BEDS (LOWER HELDERBERG).

These are the oldest beds exposed at the surface in the Lower Peninsula. Not more than 100 or 200 feet of these beds are exposed at the surface, but borings reveal over 1,200 feet, if with Orton we include in the group the salt beds (Salina). The beds are mainly buff dolomites and calcareous and argillaceous marls, associated with anhydrite and rock salt. Near the top a bed of the purest white quartz sand (often recrystallized), the Sylvania sandstone, extends persistently across Monroe County and can be traced under cover at least as far as Mount Clemens and St. Clair River. This sandstone is, of course, a good water bearer. Near Detroit, while at about 200 feet the strongly sulphureted waters of the Dundee are reached, at about 400 feet comparatively fresh potable water is met, and it seems as if it might be worth while to develop further this horizon, which is probably also encountered in Ypsilanti and Alpena. Below this sandstone the salt beds and brines of the Salina are reached. Rock salt is here in single layers often over 100 and even 200 feet thick; its aggregate thickness can not be estimated. These rock-salt beds extend apparently beneath (or at any rate skirt) the whole of the peninsula, from Alpena and St. Ignace down to a line drawn from Trenton to Muskegon. South of this line there is gypsum (or anhydrite), but not salt. A group of six wells at Trenton shows, within a few hundred yards, the exact margin of the salt basin.

This great thickness of salt suggests that there should have been a concentration, as at Stassfurt, in Germany, of the rare potash and bromine salts in the upper layers. The earlier Sand Beach analyses

dicated such concentration, but the water does not now give similar sults. The Mount Clemens, Somerville Springs, and similar waters e clearly of the nature of mother liquors.

These salt beds, like all the beds, dip away from the St. Clair and etroit rivers to the northwest, but after descending to depths of obably 3,000 to 4,000 feet, they rise again, and just north of the raits of Mackinac gypsum beds outcrop. At St. Ignace a thin bed salt is reported only 400 feet below the surface, while at Alpena ck salt is encountered within 1,000 or 1,200 feet. Though the Salina n not be sharply divided from the formation above or below, the folwing arrangement may be suggestive: at the top, dolomites and pseous marl mark a time of desiccation; then comes an arenaceous lomitic limestone passing into a glass sand—the Sylvania sandone; then some more beds with gypsum and sometimes with rock salt; en 200 feet or more of somewhat gypsiferous dolomites; and beneath em a rapid succession of thick rock-salt beds, marking probably the st and greatest period of desiccation.

NIAGARA AND CLINTON FORMATIONS.

These formations have been struck only southeast in Monroe unty, southwest from Kalamazoo, and north at Frankfort. The ost characteristic part probably belongs to the Guelph formation—e churn-drill powder being almost white—a very fine-grained doloitic limestone. It answers to Orton's description, and in accord ith his remarks of the change from southern to northern Ohio, I cognize the Rochester[1] shale only at Wyandotte. Generally toward e bottom the limestone becomes more ferruginous and, as at Wyanotte and Dundee, a "red rock," and then the red shales of the Medina e reached. Concerning the water resources of this part of the colnn little is known. Water was noted at Dundee from these beds, it there is no report of its chemical character.

HUDSON RIVER AND UTICA SHALES.

There is next a great series of shales, struck only by a few wells in xploring to the Trenton, like those at Dundee, Monroe, and at South end, Indiana, viz: (1) The Medina red and green shales at Dundee, at depth of 1,625 to 1,725 feet; (2) the Hudson River blue shales, about 0 or 400 feet thick; (3) the Utica brown or black bituminous shales, out 100 feet thick. This series is similar to the Lower Marshall, e Coldwater (Cuyahoga), and the St. Clair shale series.

[1] The Director of the United States Geological Survey has decided that hereafter in the publitions of the Survey the term *Lockport limestone* will be used in place of the term "Niagara estone," and the term *Rochester shale* in place of the term "Niagara shale," the word *Niagara* ing reserved for the designation of some higher classific unit.—EDITOR.

TRENTON LIMESTONE.

This formation has been penetrated a few feet at Monroe and at Wyandotte, somewhat further at Dundee, and again in the southwest part of the State, at Dowagiac. It is really a buff, granular, porous dolomite, with traces of gas and oil usually drowned out by a strong impure brine.

ROCK STRUCTURE AND TOPOGRAPHY.

The general structure of the rock basin, which has been described, is well shown by Pls. LXVII to LXX of Vol. V (1895), Pt. II, Michigan geological survey, which can, however, be improved by use of records since received; fig. 10 is a new section from Monroe to Charlevoix. The limestones and sandstones of the Traverse, Dundee, and Monroe make a rock ridge, which comes to the surface in Monroe County, can be distinctly traced as an escarpment, as Spencer has remarked, in the bottom of Lake Huron, and reaches land once more at Thunder Bay. From that point the ridge, though apparently broken beyond Cheboygan by cross valleys, continues nearly around to Frankfort, where the rock surface is slightly higher than at Manistee. The deep valley between this ridge and the Marshall sandstones is clearly defined in the well records in the southeastern part of the State, and seems to discharge near Algoma, where there is considerable thickness and where the depth to drift is irregular. This shale valley was overlooked on the northwest by an abrupt escarpment of Marshall sandstone, which is almost everywhere concealed, and yet within a mile the depth to rock may vary from less than 10 to 30, 40, or even 100 feet. This Marshall sandstone escarpment is more or less escalloped and ravined, as was indicated in Hillsdale County, and there are probably outlying areas or spurs of sandstone. On the main ridge of Marshall sandstone the rock floor is reported to be fairly level, and the irregularities in the drift are due to the irregularities of the moraine ridges, etc.; but in toward the coal basin, i. e., toward Mason County and around Pigeon, in Huron County, there is a system of valleys in the rock surface up to 100 feet deep. In the lower part of the Michigan series soft beds, easily cut, predominate, while the upper part, the Parma sandstone, the Bay Port limestone, etc., is more resistant, and shows an escarpment facing outward at least 10 or more feet vertically, and the valleys, as they traverse it, rapidly deepen to more than 100 feet. It is probable that some of the limestone masses which have so puzzled Winchell[1] and others have been outliers of this escarpment pushed or dragged off from the soft shales beneath and left stranded in the drift. They are particularly conspicuous, as Winchell remarks, in Oceana County, in the northwestward extension of the rock divide—which follows the Mar-

[1] Proc. Am. Assoc. Adv. Sci., 1875, p. 36.

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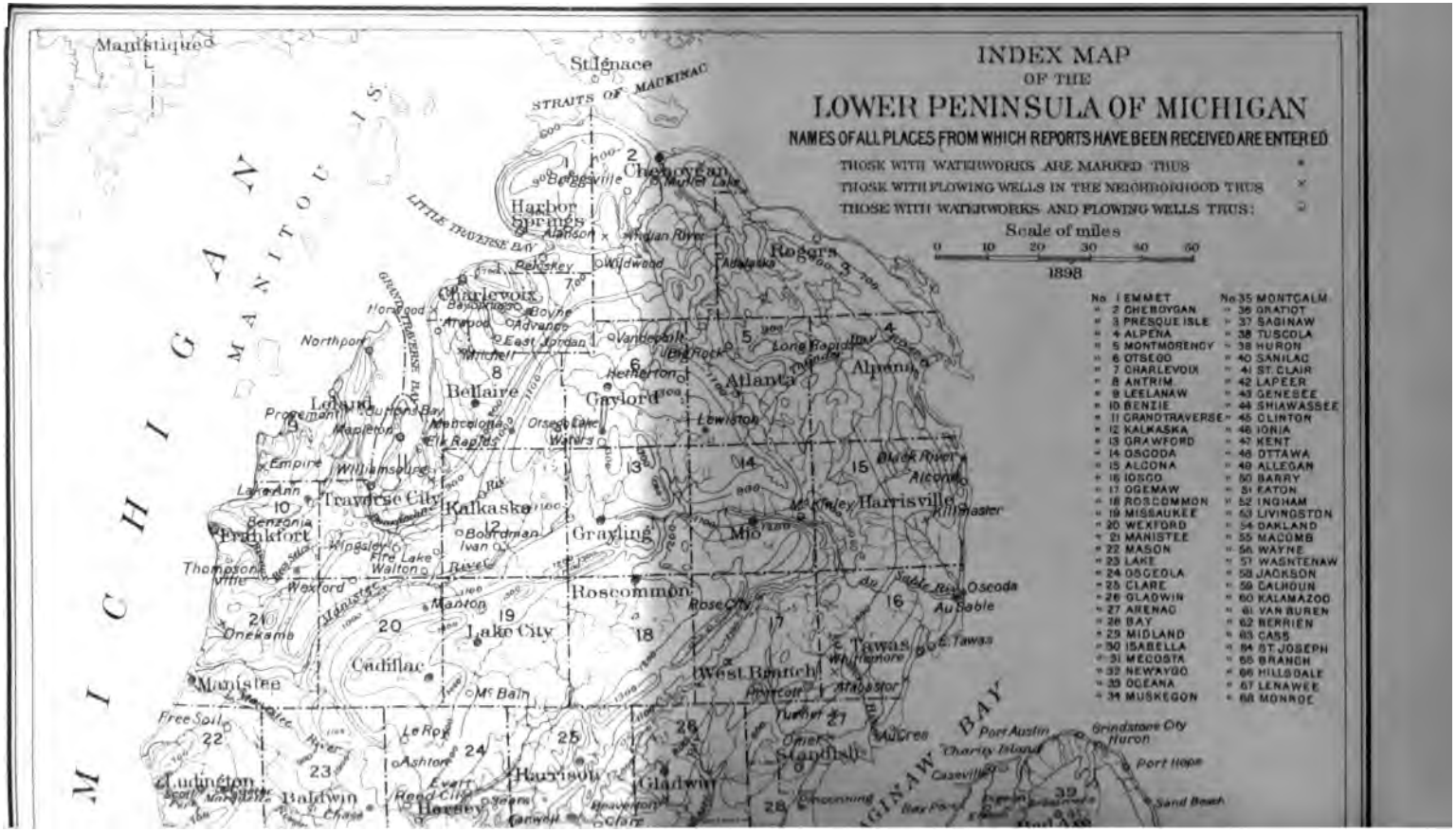
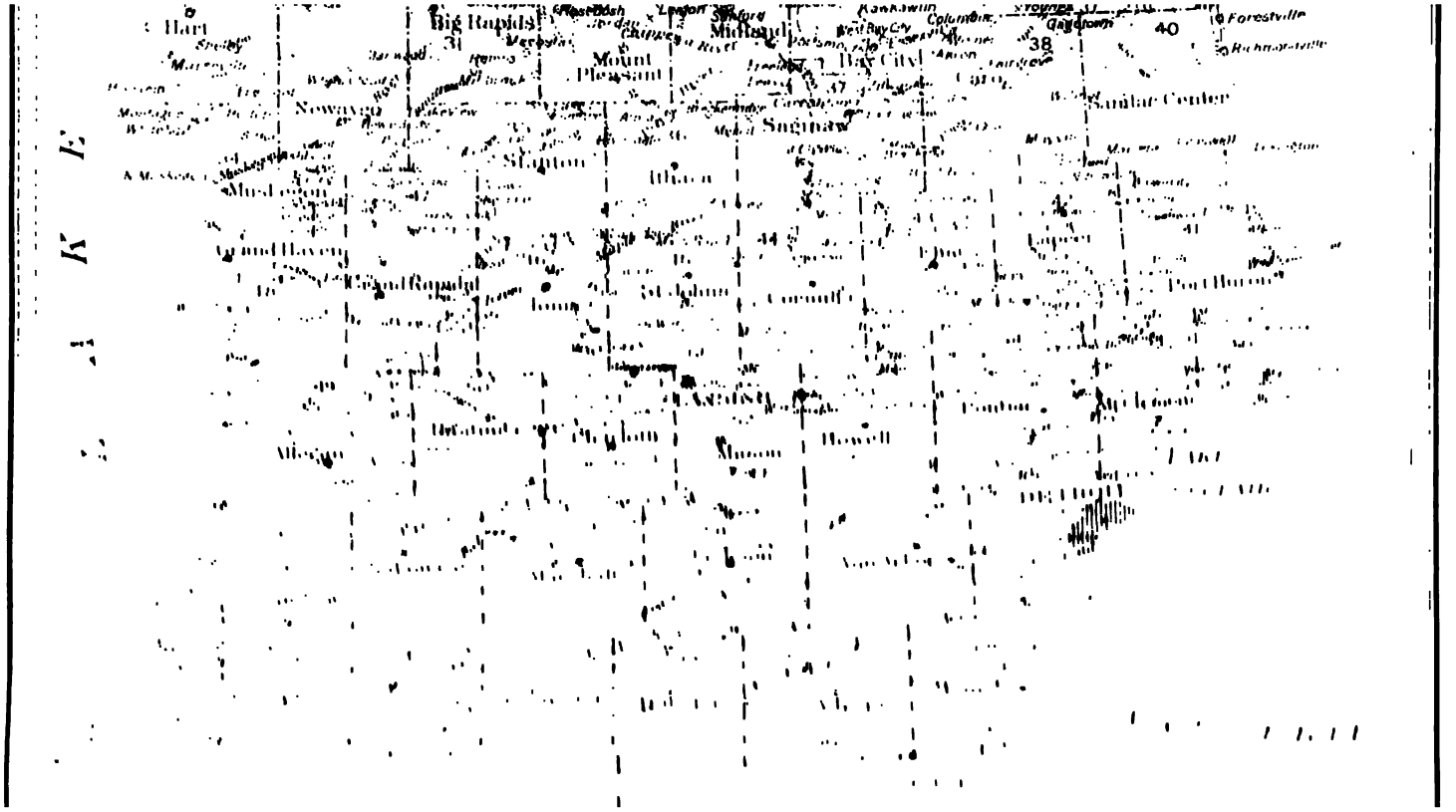

INDEX MAP
OF THE
LOWER PENINSULA OF MICHIGAN
NAMES OF ALL PLACES FROM WHICH REPORTS HAVE BEEN RECEIVED ARE ENTERED
THOSE WITH WATERWORKS ARE MARKED THUS *
THOSE WITH FLOWING WELLS IN THE NEIGHBORHOOD THUS ×
THOSE WITH WATERWORKS AND FLOWING WELLS THUS: ⊗
Scale of miles
0 10 20 30 40 50
1898
No 1 EMMET
" 2 CHEBOYGAN
" 3 PRESQUE ISLE
" 4 ALPENA
" 5 MONTMORENCY
" 6 OTSEGO
" 7 CHARLEVOIX
" 8 ANTRIM
" 9 LEELANAW
" 10 BENZIE
" 11 GRANDTRAVERSE
" 12 KALKASKA
" 13 CRAWFORD
" 14 OSCODA
" 15 ALCONA
" 16 IOSCO
" 17 OGEMAW
" 18 ROSCOMMON
" 19 MISSAUKEE
" 20 WEXFORD
" 21 MANISTEE
" 22 MASON
" 23 LAKE
" 24 OSCEOLA
" 25 CLARE
" 26 GLADWIN
" 27 ARENAC
" 28 BAY
" 29 MIDLAND
" 30 ISABELLA
" 31 MECOSTA
" 32 NEWAYGO
" 33 OCEANA
" 34 MUSKEGON
No 35 MONTCALM
" 36 GRATIOT
" 37 SAGINAW
" 38 TUSCOLA
" 39 HURON
" 40 SANILAC
" 41 ST. CLAIR
" 42 LAPEER
" 43 GENESEE
" 44 SHIAWASSEE
" 45 CLINTON
" 46 IONIA
" 47 KENT
" 48 OTTAWA
" 49 ALLEGAN
" 50 BARRY
" 51 EATON
" 52 INGHAM
" 53 LIVINGSTON
" 54 OAKLAND
" 55 MACOMB
" 56 WAYNE
" 57 WASHTENAW
" 58 JACKSON
" 59 CALHOUN
" 60 KALAMAZOO
" 61 VAN BUREN
" 62 BERRIEN
" 63 CASS
" 64 ST. JOSEPH
" 65 BRANCH
" 66 HILLSDALE
" 67 LENAWEE
" 68 MONROE
MICHIGAN
MANITOU IS.
Manitiquet
Stilgnace
STRAITS OF MACKINAC
Cheboygan
Harbor Springs
LITTLE TRAVERSE BAY
Rogers
Charlevoix
Northport
Leland
Bellaire
Gaylord
Atlanta
Alpena
Traverse City
Kalkaska
Grayling
Mio
Harrisville
Frankfort
Roscommon
Lake City
Cadillac
Manistee
Tawas
West Branch
Standish
Ludington
Baldwin
Hersey
Harrison
Gladwin
Oscoda
Au Sable
Port Austin
Grindstone City
Huron
Port Hope
Sand Beach
SAGINAW BAY


Hart
Big Rapids
Midland
Mount Pleasant
Bay City
Newaygo
Saginaw
Sanilac Center
Muskegon
Grand Haven
Grand Rapids
Port Huron
Forestville
31
38
40
44

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" 55 MACOMB
" 56 WAYNE
" 57 WASHTENAW
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" 60 KALAMAZOO
" 61 VAN BUREN
" 62 BERRIEN
" 63 CASS
" 64 ST. JOSEPH
" 65 BRANCH
" 66 HILLSDALE
" 67 LENAWEE
" 68 MONROE
Manistique
Stidnace
STRAITS OF MACKINAC
Cheboygan
Harbor Springs
LITTLE TRAVERSE BAY
Rogers
Charlevoix
Northport
Bellaire
Gaylord
Atlanta
Alpena
Lewiston
Traverse City
Kalkaska
Grayling
Mio
Harrisville
Frankfort
Roscommon
Lake City
Cadillac
Manistee
West Branch
Tawas
Standish
Port Austin
Grindstone City
Huron
Port Hope
Oscoda
Au Sable
MANITOU IS
LAKE MICHIGAN
SAGINAW BAY

LAKE
LAKE ST CLAIR
LAKE ERIE
Hart
Big Rapids
Mount Pleasant
Midland
Bay City
Caro
Sanilac Center
Newaygo
Saginaw
Stanton
Ithaca
Muskegon
Grand Haven
Grand Rapids
Ionia
St Johns
Corunna
Flint
Lapeer
Port Huron
Lansing
Pontiac
Mt Clemens
Hastings
Charlotte
Mason
Howell
Allegan
Kalamazoo
Marshall
Jackson
Ann Arbor
DETROIT
Paw Paw
St Joseph
Cassopolis
Centerville
Goldwater
Hillsdale
Adrian
Monroe
Toledo
Forestville
Richmondville
Holstein
Montague
Whitehall
N. Muskegon
Fruitport
West Olive
Holland
Douglas
Benton Harbor
Berrien Springs
New Troy
Three Oaks
Buchanan
Lexington
Croswell
Marine City
St. Clair
Grosse Isle
Rockwood
Trenton
Wyandotte
Belleville
Ypsilanti
Milan
Tecumseh
Clinton
Blissfield
Deerfield
Lulu
La Salle
Temperance
Lambertville
Ottawa Lake
Weston
Ransom
Kinderhook
Gilead
Bethel
Union
Sturgis
Constantine
Vandalia
Edwardsburg
Niles
Summerville
Galien
Bowaniac
Penn
Wakeeney
Marcellus
Decatur
Lawrence
Paw Paw
Keeler
Vicksburg
Scotts
Schoolcraft
Cooper
Climax
Battle Creek
Springfield
Bellevue
Olivet
Charlotte
Eaton Rapids
Leslie
Mason
Stockbridge
Chelsea
Dexter
Ann Arbor
Ypsilanti
Saline
Milan
Manchester
Brooklyn
Clinton
Tecumseh
Adrian
Hudson
Blissfield
Monroe
Grosse Isle
Rockwood
Trenton
Wyandotte
Belleville
Flat Rock
Grafton
Scofield
Dundee

shall sandstone around to Holland—near which there are outcrops. To the southeast around Allegan, South Haven, and Bangor, the rock surface is considerably lower. How far the softer Michigan series make a trough separating the Marshall ridge from the limestone ridge is not yet clear from the well records. Rapid variations in the altitude of the rock surface around Grand Rapids make it evident that the limestone there is much eroded. Up Grand River, at Ionia, there are other outcrops of a sandstone which is probably high up in the coal series. The rock ridge can be followed, being occasionally struck by wells, to the southeast corner of Newaygo County. From this point north the rock surface evidently falls off, for it is so deep that no ordinary wells for water encounter it, and it is only from deep explorations for salt, oil, or gas that it has been found to fall below sea level at Manistee (30 to 40 feet below tide). It is near these low points in the rock surface that the large limestone masses are found in the drift in Oceana County, and it is not unnatural to suppose that this is in a region of strong relief, whose scenery was something like that of the driftless area of Wisconsin, full of pinnacles capped with limestone. It is here, therefore, that we have carried the stream valley described on page 83, which seems to drain the most of the coal basin surrounded by the Marshall rampart.

The great depth of drift at Traverse City, with the rock bottom not yet reached, compared with Provemont, where the limestone has been struck, shows that on the northwest side again the Coldwater and St. Clair shales make a valley, though outcrops are not far away, and other facts go to support the suggestion that the limestone escarpment on this side was in bold relief and probably severely cut up. In all probability Grand Traverse Bay marks some prominent cross valley. Beyond Cheboygan Lake the limestone ridge becomes more continuous. Throughout the north half of the State the well records of depth to rock are so few that the reconstruction of the rock topography is largely guesswork, and it is necessary to fall back on the analogies of the relations of moraines to rock ridge in the lower part of the State.

PROSPECTS OF ROCK WELLS.

NORTHERN LIMESTONE DISTRICT.

From what has been said in the previous part of this paper in connection with the well reports, it appears that there is a district, from Alpena and Long Rapids to Charlevoix and north of these places, through which it will frequently be necessary, in order to get a permanent supply of water, to drill down into the limestone (Traverse or Dundee), which is often close to the surface. At moderate depths, down to about 500 feet, the water, though hard and slightly charged with hydrogen sulphide (H_2S) will be suitable for drinking. At greater depths, however, within 1,500 feet, rock salt and brines will be encountered.

NORTHERN SHALE DISTRICT.

Toward the south there is a broad district heavily covered with drift, with the rock surface probably a valley in which it will very rarely be necessary to go to rock for drinking waters, and in fact the prospect for them is not very good. The underlying rocks belong to the Carboniferous and Devonian shale series. Only here and there will a deep well, drilled for gas, brine, mineral water, etc., penetrate to the rock and find mineral water beneath the shales.

Toward the south side of this district are the sandstones of the Lower Marshall; but little is yet known of their extent.

COAL BASIN.

The coal basin occupies the center of the State, including in it the Michigan and Upper Marshall series. The basin extends from Tawas Bay probably well up toward Otsego Lake, thence to Ludington and Hart, thence down to Hillsdale County (as shown on the map, Pl. VI). Throughout this district the structure of the rocks is favorable for artesian wells, and inside the belt of moraine that surrounds it there is a very fair chance of getting a flow of water, as at Birch Run, Midland, Bay Port, Sebewaing, and elsewhere. Near the margin of this basin the Upper Marshall sandstone furnishes an abundant supply of the purest water. Toward the center of the basin the overlying Michigan series, with their highly mineralized waters, must be cased off if drinking water is desired. Still nearer the center of the basin almost all the water is slightly saline, but is still quite potable. The limits of the saline waters are roughly shown in fig. 14 (e. g., deeper wells of Saginaw, Ithaca, etc.). The deepest waters now become strong brines, the Upper Marshall becoming remarkably charged with bromine, as at Alma, Midland, and Big Rapids.

SOUTHERN SHALE DISTRICT.

This district, being the southern counterpart of the northern shale district, is the only part of the State where there is any serious difficulty in getting a satisfactory supply of water. It is divided into two parts by the projection of the Marshall sandstone nearly to the Michigan-Ohio-Indiana State boundary. To the southwest there are usually, but not always, ponds and lakes enough for city supplies, and the heavy deposits of overwash valley drift give numerous chances for wells in surface deposits. To the southeast, however, there are practically no lakes below the 800-foot contour. The surface deposits are largely lake clays and clay till, and the underlying rocks shales with subordinate sandstone streaks. These sandstones are likely to be salty or unpleasantly charged with gases. In this region, if a permanent supply can be obtained from cisterns or from the surface gravel ridges, that is probably often the best obtainable, provided due precautions are taken against surface contamination. The Berea sand-

stone seems to be usually salty. It might be worth while to see how far the sulphureted waters of the Dundee could be cased out and a

FIG. 14.—Map showing areas of shallow saline waters in Michigan.

good supply obtained from the Sylvania sandstone. There is no difficulty in this region in getting mineral waters, especially sulphureted.

SOUTHEASTERN LIMESTONE DISTRICT.

There only remains to be considered the limestone district of Monroe and southeastern Wayne counties. Here wells just down to or a little way in the rock encounter plenty of water, generally flowing chalybeate, hard, and highly charged with hydrogen sulphide (H_2S). There are plentiful flows of fresh water all the way down, until at 800 feet or less the gypsum and salt layers begin. Naturally the wells draining from the Sylvania sandstone seem to have the best supply, and it might be worth while to go down to it a little farther under cover.

ACKNOWLEDGMENTS.

General acknowledgment is due to a large number of persons who have rendered assistance, mainly by replies to schedules. Thanks are particularly due to L. L. Hubbard, State geologist of Michigan, for free use of data accumulated by the survey and for assistance in many other ways; also to my colleagues on the survey; to Prof. C. A. Davis for information, especially as to Tuscola County, and for hints too numerous to mention; to Prof. W. H. Sherzer and Mr. Cramer for information, especially concerning the southeastern part of the State; and to Dr. C. H. Gordon for information relating to Sanilac County and for hints as to Pleistocene deposits. In this last matter Mr. F. B. Taylor and Mr. Frank Leverett have assisted not only by their publications but by their kindly criticism. Especially in Pl. II data for the southwest part of the State are derived almost wholly from unpublished notes which Mr. Leverett kindly furnished, for the form of which, however, I am entirely responsible. The map in Pl. VII gives the location of those places from which reports have been received, and also indicates the location of public waterworks so far as can be ascertained from these reports, from the Manual of American Waterworks (1897), and from the Michigan Gazetteer. It also indicates, by a special sign, those localities near which flowing wells are reported. It may thus serve to indicate how thoroughly the ground has been covered and in what parts of the State information is still scanty. Above Saginaw Bay the population is sparse.

The paper is least satisfactory in regard to the water powers of the region considered. Those who know the facts consider them too valuable to publish. In this connection the paper by Mr. Robert E. Horton is a welcome addition. The water powers northwest of Saginaw Bay seem especially worth exploiting.

Finally, to the State weather service, C. F. Schneider, director, I am indebted for meteorological data.

INDEX.

Page.

ɔr power at 21
'ainfall at 26
ek, water power on 19
ɔth of drift at 72
to rock at 83
rature of wells at 56
supply of 16, 48
water power at 22
'ater power at 20
ater power at 21
ɔr, water power at 40
ɔek, water power on 21
River, water power on 20
River, water power on 20
, water power at 19
ɔek, rainfall at 26
ɔek, discharge of 32
use of water at 16
, temperature of wells at 57
', water supply of 16
ɔk, water power on 21
ɔr, water power on 20
, water power at 39
, water power at 20
le, character of water from 84–85
ver, water power on 20
la, depth to rock at 83
power at 21
River, water power on 21
am, water supply of 16
'er, water power on 19
n River, water power on 20
lls, water power at 20
ver, water power on 20
ek, water power on 21
ı, water power at 21
vater power at 21
g land formed of 65
er power at 19
r, R. C., cited on swamp drain-
e 24
er, water power on 20
water power at 21
ɔr, water powers on 19
eek, water power on 21
ix, section of well at 87
' supply of 16
ın, water supply of 16
ın River, water power on 20
ı River, water power on 19
te, variation in 17
ɔrmation, occurrence of 89
iver, water power on 18
ı, extent of 92

Page.

Coldwater River, water power on 21
Coldwater shales, character of water from 84
Coleman, depth of drift at 72
Concord, rainfall at 26
Cooley, L. E., aid by 45
Corunna, water power at 19
Crockery Creek, water power on 21
Crosman, Charles, cited on fluctuations of lake level 30
Crystal Creek, water power on 21
Cyperus, bog land formed of 65
Davis, C. A., acknowledgments to 94
observations by 56
quoted on lakes of Michigan 64
reference to 44, 72
work with 79
Deadman, W. H., mentioned 42
Delhi, water power at 40
Detroit River drainage, water power in 18
Dexter, water power at 41
Drainage, glacial 60
peculiarities of 62
reversed 63
Drift, depth of 72, 74
thickness of 75
Duck Lake, water power on 20
Dundee limestone, character and water-bearing qualities of 87–88
typical section between St. Clair shales and 86
Eaton Rapids, water power at 21
Elk Rapids, water power at 20
Elk River, water power on 20
Fall, D., mentioned 42
Fallossburg, water power at 21
Fawn River, water power on 21
Flat River, water power on 21
Flat Rock, water power at 39
Flint River, water power on 19
Fosters Station, water power at 40
Glacial drainage of Michigan 60
Glaciation in Michigan 58–60
Gordon, C. H., acknowledgments to 94
Grand Ledge, water power at 21
Grand Rapids, water power at 21
Grand River, discharge of 32
water power on 21, 22
watershed between the Saginaw 13
Grayling, water power at 20
Great Lakes, transportation on 12
Greenleaf, James L., cited on water power of Huron River 38
Hamilton, C. E., cited on swamp drainage 24

Page

Hanover, rainfall at 26
Harbor Springs, water supply of 16
wells near 76
Hog Creek, water power on 21
Horton, Robert E., mentioned 18, 49
report on run-off and water power of Kalamazoo River, by 22-38
Houghton Creek, water power on 20
Hubbard, B., cited on climate of Lake region 30
Hubbard, L. L., acknowledgments to 94
Hudson River shales, extent of 89
Hunt, water supply of 16
Huron, water power at 19
Huron County, geological column in 85
Huron River, course and character of 38-39
water powers on 18, 38-41
Irish, Charles W., cited on rainfall in California 29
Jackson, water power at 22
Kalamazoo, high water at 35-36
rainfall at 26
Kalamazoo County, prairies in 67
Kalamazoo River, course of 22-23
discharge of 31-32
distribution of crops in watershed of 25
fall and slope of 37
lakes in watershed of 24
meteorological conditions at stations on 33-34
rainfall on watershed of 26-29
topography along 24-25
water power on 21, 22-38
Lake Erie drainage, water power in 18
Lake Huron drainage, water power in 20
Lake level, fluctuations in 29-30
Lake Michigan drainage, water power in 20-22
Lake St. Clair drainage, water power in 18
Lakes of lower Michigan 64-67
Leverett, Frank, acknowledgments to 94
cited on effect of drift upon topography and drainage 23
reference to 59
Little Manistee River, water power on 21
Lowell, water power at 40
Lower Marshall sandstone, extent and water-bearing qualities of 84
Manistee River, water power on 21
Marshall, rainfall at 26
Marshall sandstone, extent and water-bearing qualities of 78-80
Medina shales, occurrence of 89
Michigan Basin, cross section of lower 79
Michigan, elevation of 17
uses of water in 11-12
water powers in 18-22
Michigan series, extent of 79
thickness of and character of water from 80
Midland, depth of drift at 72
section of well at 82
Milford, water power at 18
Mill Creek, water power on 19
Monroe beds, extent and character of 88
Monroe County, drift in 70
Mount Pleasant, depth of drift at 72

Page

Mount Pleasant, depth of rock at 83
water power at 19
water supply of 15, 48
Mudge, E. H., cited on drainage of coal basin 83
Mulletts River, water power on 20
Muskegon River, water power on 21
Newaygo, water power at 21
New Boston, water power at 20
Newell, F. H., letter of transmittal by 9
Niagara formation, occurrence of 89
North Lansing, water power at 21
Northup, F. H., and Rafter, George W., cited on water supply of Traverse City 31
Northville, water power at 18
Notepseakan River, water power on 21
Olivet, rainfall at 26
Oqueoc River, water power on 20
Owosso, water power at 19
Parma sandstone, water-bearing qualities of 80, 81
Pawpaw River, water power on 22
Petoskey, water supply of 16
water power at 20
Phillips, E. R., mentioned 43
Pigeon River, water power on 19, 20
Pine River, water power on 19
Pinnebog River, water power on 19
Precipitation, average annual 52-53
distribution of 49
long-period variations in 54-55
See Rainfall.
Pulaski, rainfall at 26
Rabbit River, water power on 21
Rafter, George W., cited on water supply of Erie Canal 30
mentioned 17
and Northup, F. H., cited on water supply of Traverse City 31
Rainfall, average annual 52-53
effect on lake level 29-30
long-period variations in 54-55
on watershed of Kalamazoo River 26-29, 35
See Precipitation.
Rainy River, water power on 20
Raisin River, water power on 18, 41
Rawsonville, water power at 40
Rice Creek, discharge of 32
Rifle River, water power on 20
River Rouge, water power on 18
Rochester, water power at 18
water supply of 16, 48
Rock Falls, water power at 15
Rose City, profile near 68
temperature of well at 57
water power at 20
wells at 17
Rouge River, water power on 21
Saginaw, water supply of 14
use of water at 13
Saginaw Bay, variation of water level in 55
Saginaw River, water power in drainage of 19
watershed between Grand River and 13
flowing wells in valley of 44

Page.
River, former lake in valley of. 66
: supply in valley of 71-72
River drainage, water power in. 19
shales, character of 85-86
s, typical section between Dun-
se limestones and 86
, depth of drift at 72
ds, extent and character of 88-89
ters, map showing area of 93
r, water power on 19
r, C. F., acknowledgments to 50, 94
mation furnished by 26
W. H., acknowledgments to 94
ioned 88
ee River, water power on 19
anch, water power on 21
um eurycarpum, bog land
rmed of 65
River, water power on 20
rron C., information furnished
y 36
'. B., acknowledgments to 94
on former lake in Saginaw Val-
y 66
ture of wells 56
ture, variations in 50-52
ple River, water power on 21
Bay River, water power on 20
rer, water power on 18

Page
Tittabawassee River, water power on ... 19
Tobacco River, water power on 19
Todd, O. H., cited on swamp drainage 24
Topography, character of 74, 75, 90-91
Traverse City, terraces near 67
use of water at 16-17
wells at 17
Trenton limestone, occurrence of 90
Typha latifolium, bog land formed of 65
University of Michigan, water supply of. 45
Utica shales, extent of 89
Vassar, water power at 19
Water level, long period fluctuations in . 54-55
short period fluctuations in 55-56
Water powers in Michigan 18-22
Weldon township, water power in 20
Wells, in the Pleistocene 67-70
methods of sinking 69
temperature of 56-57
West Branch, wells at 17
West Saginaw, use of water in 15
water supply at 16
White River, water power on 21
Whitneyville, water power at 21
Willow River, water power on 19
Winchell, A., reference to 48, 49
Woodville sandstone, extent and water-
bearing qualities of 81
Ypsilanti, water power at 18, 39, 40

DEPARTMENT OF THE INTERIOR

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UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

WER MICHIGAN MINERAL WATERS

A STUDY INTO THE CONNECTION BETWEEN THEIR CHEMICAL COMPOSITION AND MODE OF OCCURRENCE

BY

ALFRED CHURCH LANE

WASHINGTON
GOVERNMENT PRINTING OFFICE
1899

CONTENTS.

	Page.
Letter of transmittal	9
Introduction	11
Economic value of mineral waters	12
Medicinal properties	12
Salt and soda compounds	13
Bromine	13
Discussion of analytical statements	14
Difficulties	14
Reduction factors	16
Classification of analyses	17
Waters of the Great Lakes system	18
Lake Superior	23
Waters of rivers and small lakes	27
Waters from wells in unconsolidated deposits and from springs	29
Unclassified analyses	36
Analyses by Profs. R. C. and F. S. Kedzie	39
Sanitary analyses by Prof. V. C. Vaughan	44
Miscellaneous analyses	57
Waters from beds above the Marshall formation	58
Eaton Rapids, Midland, Portsmouth, Bay City, and Saginaw springs and wells	60
Waters from the Marshall formation	63
Saginaw River saline wells	63
Brines of the Marshall sandstone	67
Brines at Midland	68
Waters from the Berea grit	70
Waters from beds below the Berea grit	71
Waters from Devonian or Silurian limestones	72
Résumé	87
Appendix	89
Index	95

ILLUSTRATIONS.

		Page.
ATE I.	Map of Lower Michigan, showing locations of waters analyzed	11
II.	Geological map of Lower Michigan	16
III.	Drilling of Petoskey well	72
IV.	Map showing areas of heavily mineralized shallow waters	88
G. 1.	Cross section at Ypsilanti, showing relations of wells	75
2.	Geological column at Alma Sanitarium	83

LETTER OF TRANSMITTAL.

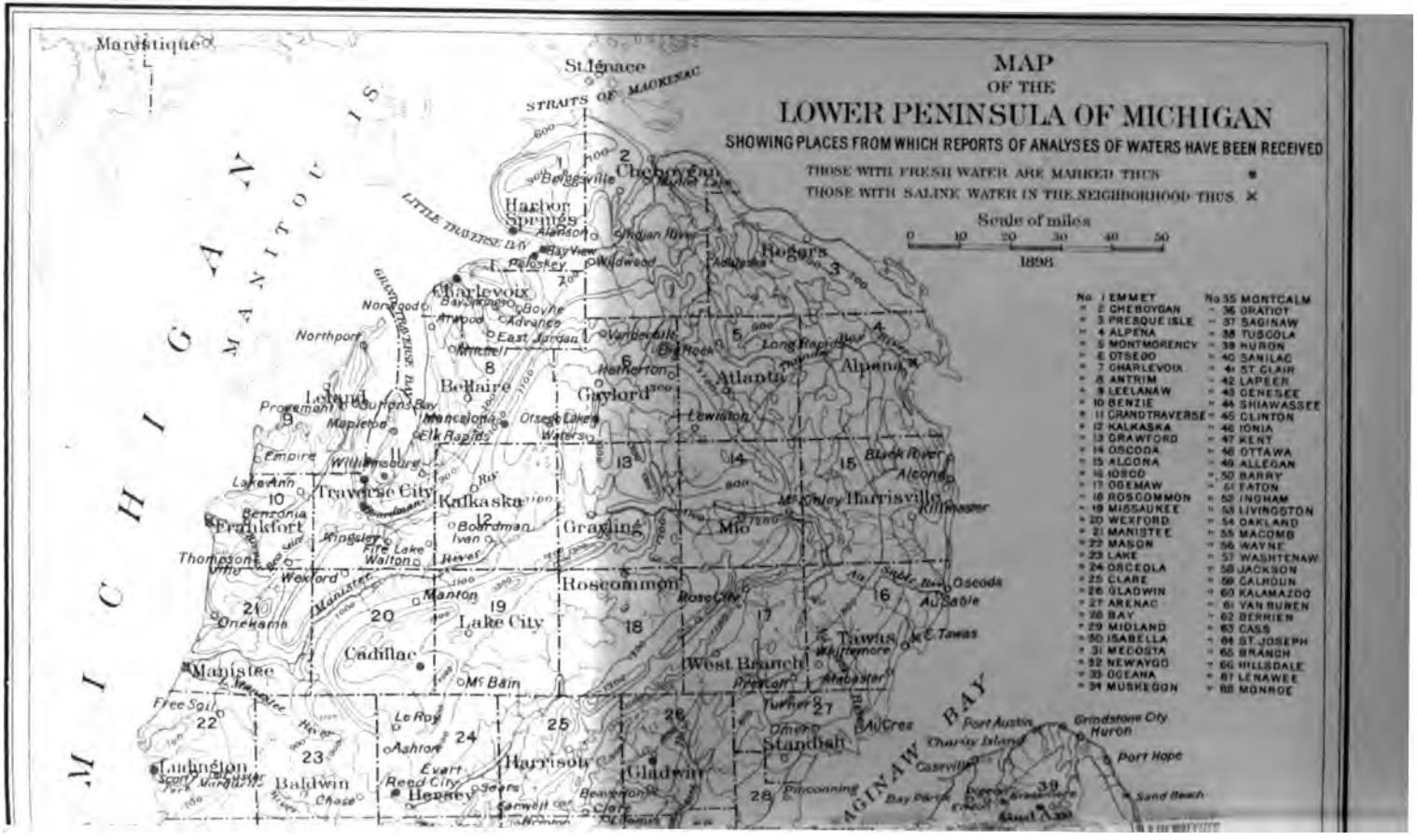
DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, May 15, 1899.

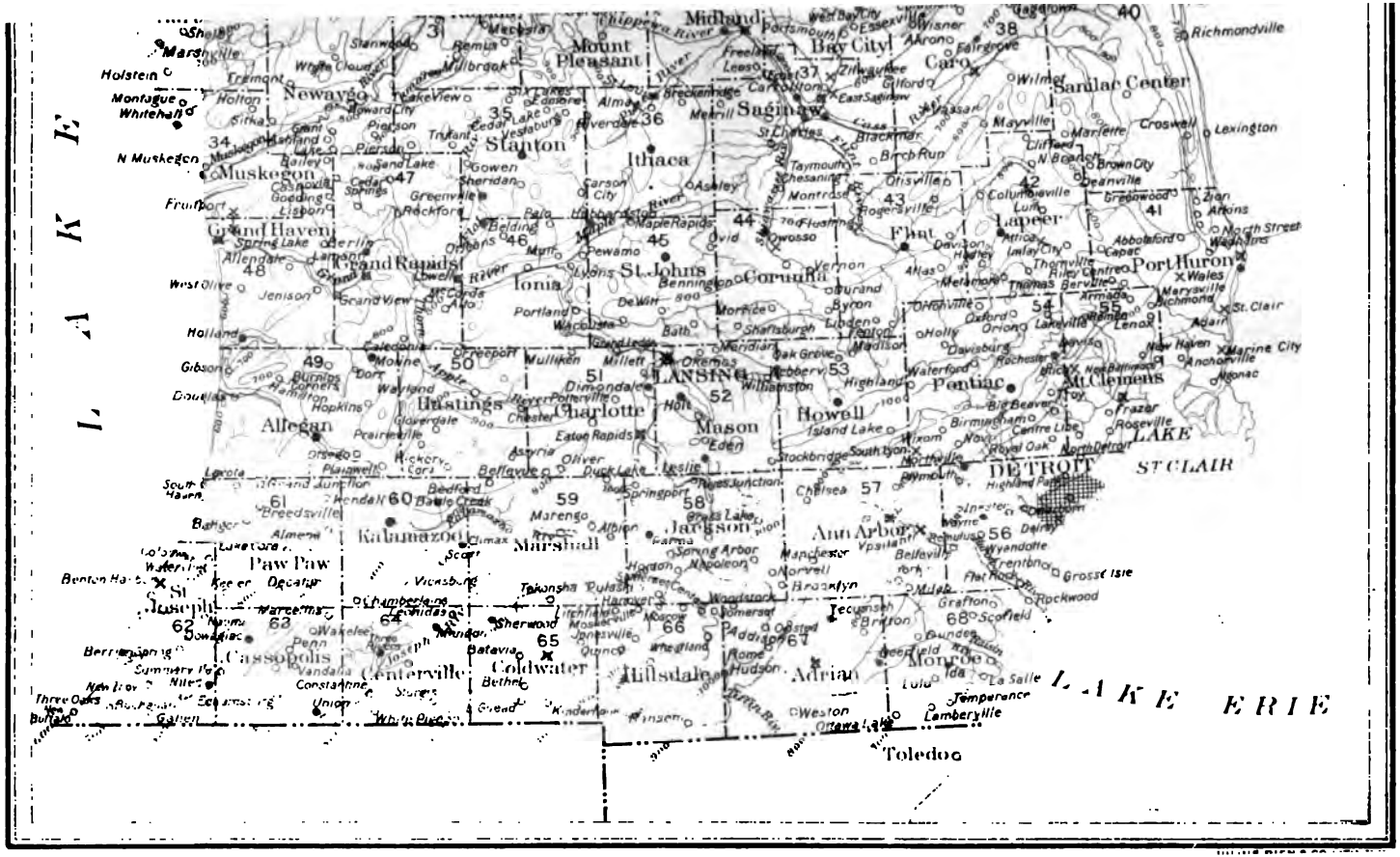
SIR: I have the honor to transmit herewith a manuscript on the mineral waters of the Lower Peninsula of Michigan, by Dr. Alfred Church Lane, now State geologist of Michigan, and to recommend that it be printed as one of the series of Water-Supply and Irrigation Papers. This is a continuation of Water-Supply Paper No. 30, entitled Water Resources of the Lower Peninsula of Michigan. The original plan was to have this and related information published as one report or monograph. It has been considered desirable, however, to issue the separate chapters or groups of chapters of the report as originally designed in pamphlet form, in order to insure an earlier publication and to facilitate the completion of portions for which an unexpected wealth of detail has been found. In this part of the report the water analyses have been brought together and discussed, particular attention having been paid to the relation which exists between the chemical composition and the geological horizons or mode of occurrence of the waters carrying mineral matter in solution.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

HON. CHARLES D. WALCOTT,
Director United States Geological Survey.


MAP
OF THE
LOWER PENINSULA OF MICHIGAN
SHOWING PLACES FROM WHICH REPORTS OF ANALYSES OF WATERS HAVE BEEN RECEIVED
THOSE WITH FRESH WATER ARE MARKED THUS ●
THOSE WITH SALINE WATER IN THE NEIGHBORHOOD THUS ✕
Scale of miles
0 10 20 30 40 50
1898
No. 1 EMMET
" 2 CHEBOYGAN
" 3 PRESQUE ISLE
" 4 ALPENA
" 5 MONTMORENCY
" 6 OTSEGO
" 7 CHARLEVOIX
" 8 ANTRIM
" 9 LEELANAW
" 10 BENZIE
" 11 GRANDTRAVERSE
" 12 KALKASKA
" 13 CRAWFORD
" 14 OSCODA
" 15 ALCONA
" 16 IOSCO
" 17 OGEMAW
" 18 ROSCOMMON
" 19 MISSAUKEE
" 20 WEXFORD
" 21 MANISTEE
" 22 MASON
" 23 LAKE
" 24 OSCEOLA
" 25 CLARE
" 26 GLADWIN
" 27 ARENAC
" 28 BAY
" 29 MIDLAND
" 30 ISABELLA
" 31 MECOSTA
" 32 NEWAYGO
" 33 OCEANA
" 34 MUSKEGON
No. 35 MONTCALM
" 36 GRATIOT
" 37 SAGINAW
" 38 TUSCOLA
" 39 HURON
" 40 SANILAC
" 41 ST. CLAIR
" 42 LAPEER
" 43 GENESEE
" 44 SHIAWASSEE
" 45 CLINTON
" 46 IONIA
" 47 KENT
" 48 OTTAWA
" 49 ALLEGAN
" 50 BARRY
" 51 EATON
" 52 INGHAM
" 53 LIVINGSTON
" 54 OAKLAND
" 55 MACOMB
" 56 WAYNE
" 57 WASHTENAW
" 58 JACKSON
" 59 CALHOUN
" 60 KALAMAZOO
" 61 VAN BUREN
" 62 BERRIEN
" 63 CASS
" 64 ST. JOSEPH
" 65 BRANCH
" 66 HILLSDALE
" 67 LENAWEE
" 68 MONROE
MICHIGAN
MANITOU IS.
STRAITS OF MACKINAC
LITTLE TRAVERSE BAY
GRAND TRAVERSE BAY
SAGINAW BAY
Manistique
St. Ignace
Cheboygan
Harbor Springs
Petoskey
Rogers
Charlevoix
Northport
Leland
Bellaire
Gaylord
Atlanta
Alpena
Traverse City
Kalkaska
Frankfort
Grayling
Mio
Harrisville
Roscommon
Lake City
Cadillac
Manistee
West Branch
Tawas
Standish
Ludington
Baldwin
Hesperia
Harrison
Gladwin
Port Austin
Grindstone City
Huron
Port Hope
Sand Beach


LAKE MICHIGAN
LAKE ERIE
LAKE ST CLAIR
Muskegon
Grand Haven
Grand Rapids
Holland
Allegan
Hastings
Ionia
Stanton
Newaygo
Mount Pleasant
Midland
Bay City
Saginaw
Ithaca
St. Johns
Corunna
Owosso
Flint
Lapeer
Caro
Sandusky
Port Huron
Pontiac
Mt. Clemens
DETROIT
Howell
Mason
LANSING
Charlotte
Eaton Rapids
Kalamazoo
Marshall
Jackson
Ann Arbor
Paw Paw
St. Joseph
Cassopolis
Centreville
Coldwater
Hillsdale
Adrian
Monroe
Toledo
Richmondville
Lexington
Croswell
Marlette
Mayville
Richmond
Marysville
St. Clair
Marine City
Algonac
New Haven
Lenox
Romeo
Armada
Ray Centre
Capac
Lapeer
Imlay City
Attica
Davison
Flushing
Fenton
Linden
Brighton
Milford
Ypsilanti
Saline
Chelsea
Dexter
Manchester
Tecumseh
Clinton
Blissfield
Morenci
Hudson
Grand Junction
Lawrence
Paw Paw
Decatur
Dowagiac
Niles
Buchanan
Three Oaks
Berrien Springs
Vicksburg
Schoolcraft
Portland
Ionia
Lowell
Saugatuck
Douglas
Holland
Zeeland
Hudsonville
Jenison
Grand Haven
Muskegon
Whitehall
Montague
Holton
Fremont
Shelby
Marshville
Holstein
Newaygo
Fremont
Ludington
Manistee
Frankfort
Beulah
Kalkaska
Gaylord
Alpena
Harbor Springs
Petoskey
Boyne City
Charlevoix
Cheboygan
Mackinaw City
Sault Ste. Marie
Ontonagon
Bessemer
Ironwood
Iron River
Marquette
Escanaba
Menominee
Iron Mountain
Crystal Falls
Ishpeming
Negaunee
Sturgeon Bay
Green Bay
Marinette
Oconto
Peshtigo
Stephenson
Wausaukee
Crivitz
Pembine
Niagara
Florence
Iron River
Ashland
Bayfield
Washburn
Superior
Duluth
Hibbing
Virginia
Ely
Grand Marais
Tower
Ely
Cloquet
Hinckley
Moose Lake
Carlton
Cook
Orr
Ely
Virginia
Hibbing
Chisholm
Grand Rapids
Deer River
Bemidji
Cass Lake
Walker
Hackensack
Pine River
Brainerd
Crosby
Ironton
Aitkin
Cromwell
Wright
McGregor
Tamarack
Palisade
Aitkin
Hill City
Kerrick
Moose Lake
Sandstone
Pine City
Rush City
Cambridge
Isanti
Braham
Mora
Milaca
Princeton
Cambridge
Isanti
Stacy
Lindstrom
Chisago City
Taylors Falls
Shafer
Center City
Lake City
Red Wing
Zumbrota
Pine Island
Oronoco
Rochester
Stewartville
Dodge Center
Kasson
Mantorville
Byron
Dover
Eyota
Chatfield
Lanesboro
Preston
Fountain
Harmony
Spring Valley
Rushford
Peterson
Caledonia
Houston
Hokah
Brownsville
Wykoff
Fillmore
Chatfield
Lanesboro
Preston
Fountain
Harmony
Spring Valley
Rushford
Peterson
Caledonia
Houston
Hokah
Brownsville
Wykoff
Fillmore
Lake City
Red Wing
Zumbrota
Pine Island
Oronoco
Rochester
Stewartville
Dodge Center
Kasson
Mantorville
Byron
Dover
Eyota

LOWER MICHIGAN MINERAL WATERS: A STUDY INTO THE CONNECTION BETWEEN THEIR CHEMICAL COMPOSITION AND MODE OF OCCURRENCE.

By ALFRED CHURCH LANE.

INTRODUCTION.

This paper is the outcome of certain work in the Lower Peninsula of Michigan which I undertook for the State survey in 1895, and was originally planned as Chapter V of a paper of which the first four chapters have appeared as Water-Supply Paper No. 30.[1] The remainder of the material will be published in a later number of this series. To these two pamphlets frequent reference must be made, and they should be considered supplementary to the present paper.

In the region of the Saginaw Valley the country is exceedingly flat, and rock exposures are rare, so that for light on the detailed geology of the subsurface rocks of the region we are compelled to rely on well records—largely the untrustworthy data derived from pulverized drillings and the inferences that can be drawn therefrom concerning the rock topography—and on the characters of the waters. It was found, however, that the waters gave important objective clues, and our party carried a testing case of barium chloride, silver nitrate, ammonium oxalate, and tannic acid, a urinometer, and a thermometer, instead of the geologist's hammer. The work I had previously done in connection with the preparation of Volume V of the State reports led me to think that in general it was probably true that the various geological horizons yielded characteristic waters; therefore during the year 1897, with the guidance and support of Mr. F. H. Newell, I attempted, by means of circulars and personal visits, to extend my investigations of the waters of Michigan. I met with such hearty cooperation from the chemists connected with State institutions—Profs. R. C. Kedzie and F. S. Kedzie, of the State Agricultural College, Prof. A. B. Prescott, of the State University, and Prof. V. C. Vaughan—that the analytical material outgrew the limits of a chapter, and I began to gain a somewhat complete idea of the chemico-geological relations of the waters of the State.

[1] Water resources of the Lower Peninsula of Michigan, by Alfred C. Lane: Water-Supply and Irrigation Paper No. 30, 1899.

Besides the gentlemen named, who have contributed many analyses, I owe acknowledgments to many other chemists who have also contributed or verified analyses for me—Messrs. Edgar and Mariner, of Chicago, Prof. S. P. Duffield, C. A. Tunnell, and Geo. L. Heath—and to resort proprietors, secretaries of water boards, and others, too numerous to mention here, who have answered circulars of inquiry.

It is not the purpose of this report to treat the general subject of water resources or water supply, which has been discussed in a general and somewhat cursory way in Water-Supply Paper No. 30, and will be taken up for the different localities in a later paper, but to show that the chemical composition of water depends on the geological occurrence, so that from a given geological stratum at a given depth a certain kind of water may be expected; and that, vice versa, the geological horizon can be inferred to a certain extent from the character of the water.

To physicians and others who are interested in the famous mineral resources of the State in a practical way, I would recommend, in addition, the pamphlet issued by the State board of health, entitled Michigan, a Summer and Health Resort, compiled by Roberts P. Hudson, Lansing, 1898. That paper is fully illustrated and contains much practical information about railroad fares, etc. At the same time the present paper, since it contains the most complete collection of analyses to date, may be of service in pointing out waters of similar character, among which a choice can be based on climate or other considerations. It will also assist in a study of the drinking-water supply in connection with disease, by giving an idea of the normal percentages of chlorine, organic matter, etc., deviation from which must be regarded with suspicion.

ECONOMIC VALUE OF MINERAL WATERS.

MEDICINAL PROPERTIES.

The various inorganic impurities which unfit water for domestic and ordinary uses may be of value from a medicinal point of view. Thus the waters of many wells in the western part of Huron and the northwestern part of Tuscola County are laxative to men and cattle not accustomed to them, though regular users may not experience such effects. Sodium sulphate is a common laxative constituent in Saginaw waters.

The mineral table waters are derived from various sources, largely sandstones or the surface gravels. The Moorman well at Ypsilanti is concentrated to throw down the lime salts and then diluted and charged with CO_2. Other table waters also seem to be diluted salines. The main horizon for bathing purposes developed at Ypsilanti, Mount Clemens, Alma, Benton Harbor, etc., is that of limestones immediately underlying the Devonian black shales. In the Berea formation just above, and again upon entering the Traverse or Hamilton formation, a very salty mineral water, with gas or oil, is struck, and in the upper Hel-

derberg (Dundee limestone) a water strongly mineralized with hydrogen sulphide. Unfortunately care is rarely taken to separate the constituents of the different flows. There are distinct indications that the first "bitter" water struck in the lower Helderberg contains in concentration rarer constituents, the earthy chlorides and H_2S, and that what is added below is mainly salt.

For the Mount Clemens wells it is customary to continue down until a satisfactory buoyancy, measured with the salinometer, is obtained, so that bathers can feel the strength of the water.

The waters from the upper Dundee (Corniferous, or upper Helderberg) or Mackinac limestone are usually strongly sulphated, and even where fresher at their margin, as at Petoskey, they are still characteristically sulphureted.

The Big Rapids well is apparently from a different horizon, the Marshall sandstone, as encountered in Midland, St. Johns, and Alma (upper water).

From these waters the salts can be extracted for medicinal purposes, as at Ypsilanti, Alma, and Big Rapids, or for their general value.

SALT AND SODA COMPOUNDS.

The production of common salt is a well-known industry of Michigan, fully treated in recent reports of the United States Geological Survey, so that only brief mention is necessary here. The State has produced altogether about 75,000,000 barrels (of 284 pounds), and in 1898 produced about 4,171,916 barrels. The production has been dying out in the Saginaw Valley, as the supply of lumber waste for fuel disappeared, and in Huron County, once lined with salt blocks, only one is left, the profit of which comes from local trade; but with the development of local coal fields the industry will be revived. On the other hand, the industry is increasing around Manistee, and also along the Detroit River, from Detroit to Trenton, where the production of salt is closely allied with that of soda ash, bleaching powder, etc. This latter district is exceptionally favored in possessing strong pure brines, strong and pure limestone, and excellent transportation facilities. Near Alpena the same favorable conditions exist, but that region is not yet developed. It has been proposed to mine the salt near Detroit, instead of pumping it, as has hitherto been the universal rule, and thus convert the deposit from a water resource to a mineral resource. While there is no law against pumping the salt out from under a man's property without compensation, it is illegal to mine it, so that pumping has the advantage of evading royalties. Newspapers report that the difficulty of sinking a shaft in face of heavy flows of water is the chief obstacle.

BROMINE.

Among the most important minor ingredients of the Michigan brines is bromine. The analyses from Midland (Nos. 281–284), Alma (Nos. 327–329), and Big Rapids (No. 278) are noteworthy for this constituent;

the Sand Beach (Nos. 328–336) and later analyses should also be compared.

The most active manufacture of bromine is at Midland, where the brine is treated for this product alone by the Dow process. The bromine seems to be concentrated in the deeper central parts of the basin, and to be more abundant in the Marshall than in any other formation.

The analyses also show other ingredients of value, but their exploitation has not gone far yet. The most promising field for further study and exploitation appears to be that of potash. Patents have been issued for the use of mother liquors of brines as an electric excitant, and the use of calcium chloride in preserving fruit, in drying, in refrigerating, and in the manufacture of artificial stone, is well known. The utilization of mother liquors has not gone far as yet.

DISCUSSION OF ANALYTICAL STATEMENTS.

DIFFICULTIES.

The analyses given in this paper are stated in various ways, according to the practice of the chemist who prepared them. I have tried to convert them all into the uniform system of grams per kilogram or parts per thousand. But it is at present practically impossible to reduce them to absolute uniformity.

In the first place, they are variously stated in grams per liter, grains per gallon, and parts per thousand, per hundred thousand, or per million. In regard to the former statements there are two uncertainties that arise. First, is the gallon imperial or United States? In most cases I have been able to remove this ambiguity. Second, was the specific gravity of the water taken into account, or was it neglected, as is customary in potable waters?[1] In other words, was the gallon or liter weighed or measured? Professor Prescott and T. Tonnelé state the results of their analyses both in parts per million and in grains per United States gallon, allowing for the specific weight of the gallon, although often only one statement is published. Professor Kedzie uses the imperial gallon of 10 pounds (70,000 grains), which is really a weight, not a measure. Professor Duffield also has used the imperial gallon, but of late uses the United States gallon of 231 cubic inches. Both weigh the waters and the specific gravity does not enter into the computation. Professor Vaughan reports in parts per million. The water is usually measured and the specific gravity neglected, as his sanitary analyses are potable waters with specific weight usually unity. Occasionally, as at Mount Pleasant, this introduces a sensible error. Messrs. Edgar and Mariner, of Dearborn Chemical Works, use the United States gallon of 231 cubic inches. In doubtful cases the imperial gallon can often be recognized by the fact that the figures of the analysis will be divisible by 7. In

[1] Missouri Geological Survey, Vol. III., p. 22.

most other cases, but not in all, I have been able to ascertain definitely, by personal inquiry, concerning this matter. The United States gallon is commonly used by the mechanical profession (for instance, by the Railway Master Mechanics' Association), and therefore generally in analyses of boiler waters. It is much to be desired that all analyses should be stated explicitly in grams per kilogram—i. e., in parts per thousand by weight—for even statements in grams per liter are sometimes really in grams per kilogram. If this form of statement is not considered so intelligible as some other expression, a note might be added calling attention to the fact that, neglecting the specific gravity, one gram per kilogram, or one part per thousand, is practically 1 ounce per cubic foot, or 1 pound avoirdupois in 120 gallons. I have restated most of the analyses in parts per thousand by weight, but, as a check, in the case of newly published analyses, have also given the original figures in italics.

But if these difficulties are once surmounted there remains, in the second place, an even more serious obstacle in the fact that the partition of acids among bases is largely a matter of choice. For instance, the bromine is sometimes given as sodic and sometimes as magnesic bromide. This must necessarily be the case so far as real combinations are concerned, and there are no universally adopted conventions. Even the few laws more or less made out, such as that $CaCO_3$ is insoluble in a saturated brine, are not always followed (see analysis No. 312). When the acids and the bases have also been given separately I have given this form also, but such a statement seems less suggestive; perhaps were it more used it would not seem so.

Finally, there is the fact that a mineral water, especially when charged with gas, as most of them are, is exceedingly unstable, and when concentrated extremely corrosive, as is witnessed by the rapid destruction of casings and bathroom fixtures. This also makes analyses uncertain and hard to compare.

Among the constituents most puzzling in this respect are the carbonates and bicarbonates, especially of iron. It is practically impossible to get the same amount of CO_2 from a carbonated water, and it is probable that more than three grains to the gallon of $CaCO_3$ (0.04 per thousand) can not ordinarily exist in a noncarbonated water, the excess of lime shown in so many analyses being in the form of calcium bicarbonate. At the Agricultural College, from the average of the results of tests by a class of from seven to ten students, the hydrant water from a deep artesian well contains 4.75 degrees of temporary and 4.714 degrees of permanent hardness, the total hardness being 9.605. After aeration and heating in the purifier the hardness was reduced to 1.68 degrees temporary and 2.554 degrees permanent, or 4.237 degrees in all. A series of tests of samples of lake and well water collected by D. J. Hale and analyzed for free CO_2, $CaCO_3$, and $MgCO_3$ by A. N. Clark, showed free CO_2 ranging from 0.0 to 66 parts per million, using phenol phthalein

as an indicator. The same thing is even more true of iron. According to Schweitzer,[1] in a chalybeate water with much gypsum one-fourth of the iron is present as carbonate and three-fourths as sulphate. Yet some analyses show more $CaCO_3$ than can be present except dissolved in H_2CO_3.

On the other hand, field observations about mineral wells have convinced me that in many cases the iron has been precipitated before the sample reached the chemist, and therefore escaped analysis. The effect of iron in solution is so marked on tea, and in precipitation as boiler or teakettle scale it is so conspicuous, that the field observer can hardly be mistaken in noticing it. But the question may often arise whether the iron is an original and essential constituent of the water or is derived from the casing of the well.

Other observations, such as exhalations and deposits, as well as the quantity and character of the boiler scale, etc., serve as checks on analyses. When, as Professor Sherzer has pointed out, native sulphur and celestite are crystallized together, as they are so characteristically at Scofield, it can hardly be amiss to assume that a trace of strontia was present in the sulphureted water, even though it is but rarely noted in the analyses. In this connection the amount of Sr shown in the analysis of Lake Superior water is noteworthy. Among the analyses those of waters from the Dundee limestone most frequently mention SrO.

Again, in Michigan, as elsewhere, certain algæ luxuriate and grow with remarkable rapidity in the deeper bicarbonated waters.

REDUCTION FACTORS.

Considering all the uncertainties mentioned as inherent in analyses, and the fact that by various methods of computation the number of grains to the United States gallon varies from 58,418.6092 to 58,372.3, the approximate reduction factors cited below are usually sufficiently accurate. Reduction of analyses from grains per United States gallon have been made by slide rule. For further details see report by Dr. A. C. Peale,[2] and references there given.

Table of equivalents.

1 United States liquid gallon = 231 cubic inches = 8.33888 pounds avoirdupois = 58,372.3 grains = 8 wine pints.

1 imperial gallon = 277.274 cubic inches = 10 pounds avoirdupois = 70,000 grains.

1 liter = 0.264179 United States liquid gallon = 0.22009 Imperial gallon.

1 gram = 15.432 grains.

Approximations.

1 part per thousand by weight = 1 gram per kilogram, or (neglecting specific gravity) = 1 gram per liter = 1 ounce per cubic foot.

To reduce grains per imperial gallon to grams per liter divide by 70.

To reduce grains per United States gallon to grams per liter multiply by 1.2 and divide by 70.

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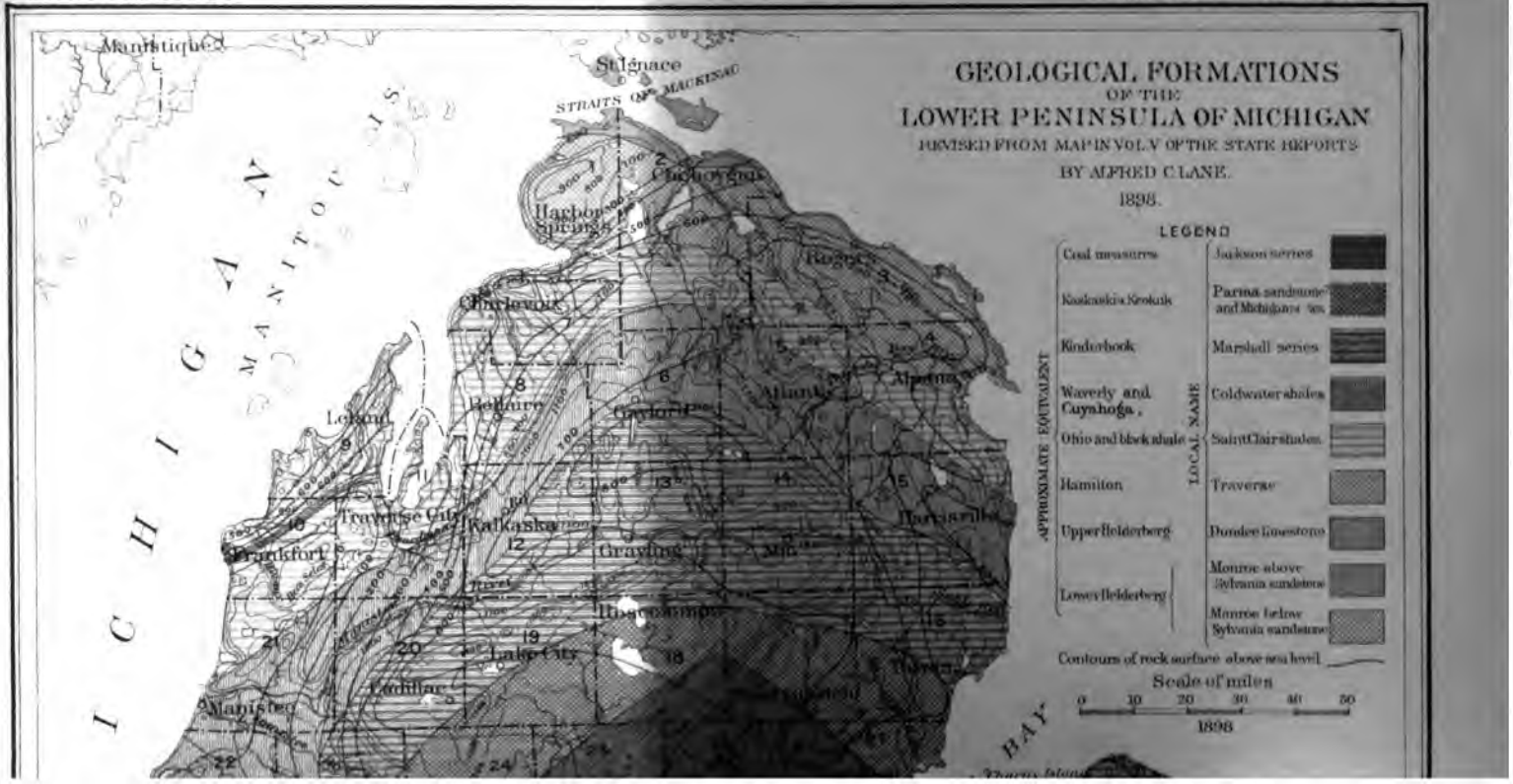
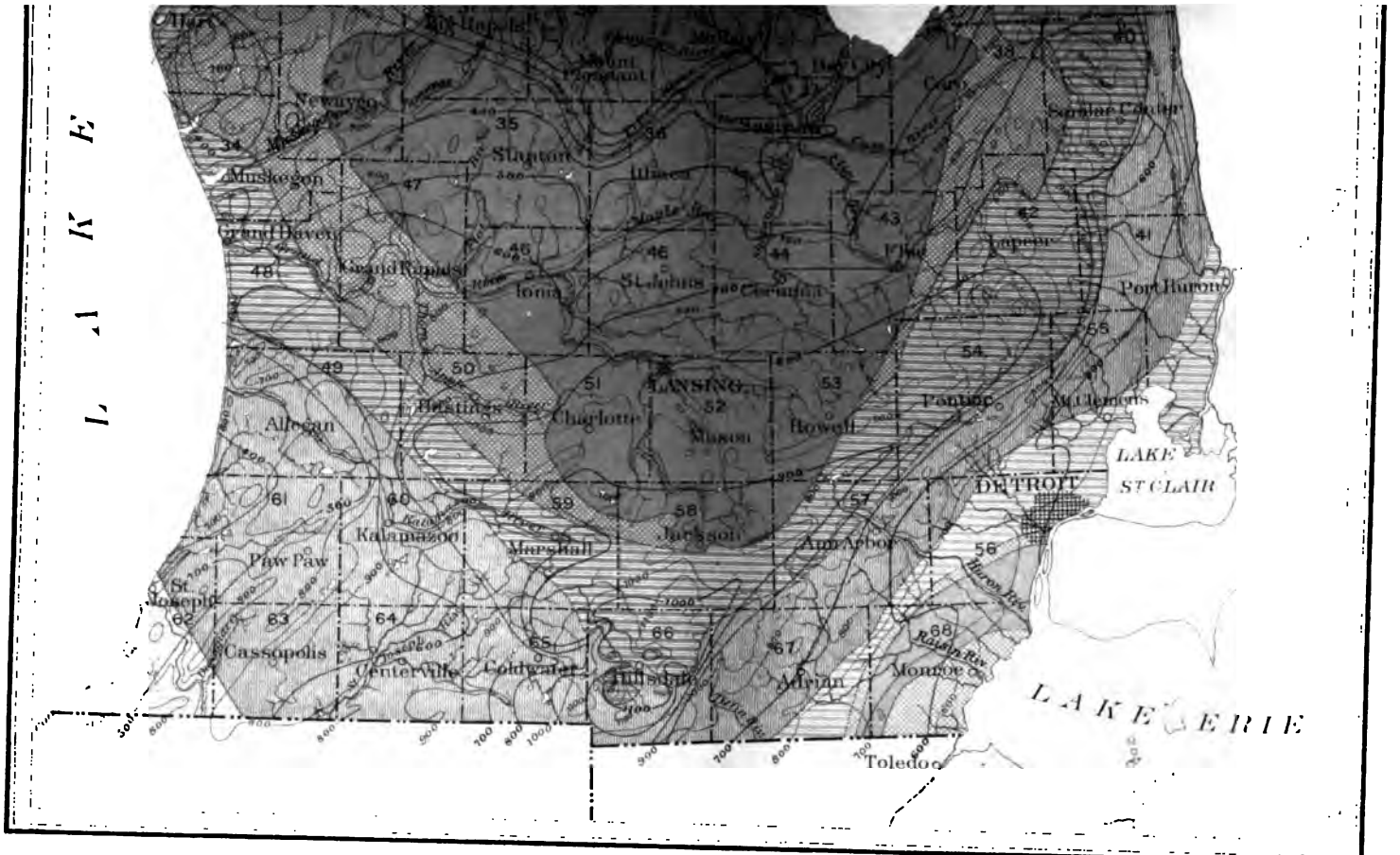
[1] Missouri Geological Survey, Vol. III, p. 19.

[2] *Natural mineral waters of the United States*, by A. C. Peale: Fourteenth Ann. Rept. U. S. Geol. Survey *(1892-93)*, Part II, 1894, pp. 49-88.


GEOLOGICAL FORMATIONS
OF THE
LOWER PENINSULA OF MICHIGAN
REVISED FROM MAP IN VOL. V OF THE STATE REPORTS
BY ALFRED C. LANE.
1898.
LEGEND
APPROXIMATE EQUIVALENT
Coal measures
Kaskaskia Keokuk
Kinderhook
Waverly and Cuyahoga
Ohio and black shale
Hamilton
Upper Helderberg
Lower Helderberg
LOCAL NAME
Jackson series
Parma sandstone and Michigan series
Marshall series
Coldwater shales
Saint Clair shales
Traverse
Dundee limestone
Monroe above Sylvania sandstone
Monroe below Sylvania sandstone
Contours of rock surface above sea level
Scale of miles
0 10 20 30 40 50
1898
Manistique
St. Ignace
STRAITS OF MACKINAC
Cheboygan
Harbor Springs
Charlevoix
Rogers
Alpena
Atlanta
Bellaire
Gaylord
Leland
Traverse City
Kalkaska
Frankfort
Grayling
Mio
Harrisville
Hoggatum
Lake City
Cadillac
Manistee
Tawas
LAKE MICHIGAN
LAKE HURON
BAY


LAKE
Newaygo
Stanton
Muskegon
Grand Haven
Grand Rapids
Ionia
St. Johns
Owosso
Lapeer
Port Huron
Sanilac Center
Allegan
Hastings
Charlotte
LANSING
Mason
Howell
Pontiac
Mt. Clemens
LAKE ST CLAIR
DETROIT
Kalamazoo
Marshall
Jackson
Ann Arbor
Paw Paw
St. Joseph
Cassopolis
Centerville
Coldwater
Hillsdale
Adrian
Monroe
Toledo
LAKE ERIE
Huron Riv.
Raisin Riv.

To reduce grains per imperial gallon to grains per United States gallon multiply by $\frac{5}{6}$.

Roughly, to reduce degrees salinometer or urinometer, etc.:

Urinometer reading = excess of specific gravity over 1 in thousandths = 2 × salinometer reading = 8 × per cent of salt or the Beaumé reading.

In estimating flows:

1 pail is usually 3 gallons.

1 barrel is usually 31½ gallons = 4 bushels = 128 quarts; sometimes 3 bushels.

1 cubic foot = 1,000 ounces fluid or avoirdupois = 30 quarts, roughly.

1 cubic foot per second = 30 quarts per second = about 150 3-gallon pails a minute = 20,000 4-bushel barrels a day = about 650,000 gallons a day.

In the Saginaw Valley the flow of the brine wells was estimated by noting the number of seconds required to fill a pail when pumping as hard as possible without pounding. Thus, a well might be known as an eight-, a ten-, or a twelve-second well, and when all were pumped a well of eleven seconds would fall off to twenty seconds.

CLASSIFICATION OF ANALYSES.

The geological occurrence and the chemical character of water are clearly interdependent, so that with some probability one may be inferred from the other. It has therefore seemed best to group together, for the purposes of comparison and study, analyses from geologically similar sources rather than to follow the alphabetical order. The analyses are generally arranged also in order of increasing concentration—i. e., of increase in the total amount of solids. To this rule there are, however, some exceptions, for I have grouped together analyses of waters from the same place and from substantially the same source, where the presumption is that the variation in concentration is accidental. The rather large groups of sanitary analyses of unknown geological environment, which I owe to Professor Vaughan and to Profs. R. C. and F. S. Kedzie, being fuller in some points and not so full in others, have been kept together, so that they may be more easily tabulated and compared. I have also grouped in a separate section those analyses the geological relations of which were somewhat uncertain, and which I did not therefore care to make use of in drawing deductions as to the character of the waters of the different strata.

The alphabetical index at the end of the paper will enable one to study the variation of chemical composition in waters from wells of varying depths at the same place. Among the places most instructive in this respect are Saginaw, Bay City, Midland, Alma, Detroit, and Ypsilanti.

The waters may be divided geologically into waters of the Great Lakes system, of rivers and smaller lakes, of wells and springs in the unconsolidated deposits, and of wells from beds above the Marshall (which are stronger in sulphates), in the Marshall, in the Berea grit (saline), and in beds below the Berea (sulphureted). To each group is given a section below.

In all analyses the results are in parts per thousand (grams per ilogram) unless otherwise stated. Where two sets of figures are iven, the lower refer to parts per thousand. This is done in the case f analyses not, to my knowledge, elsewhere on record, and for which I ave had to compute the lower figures from other forms of statement. s a check the original figures are given above them in italics.

In all the sanitary analyses by Professor Vaughan the color is clear, nless otherwise stated, the reaction neutral, and the water odorless, nd this is the presumption in the case of other sanitary analyses. 'rofs. F. S. and R. C. Kedzie jointly furnished me with a list of analyses, ne credit for which belongs sometimes to one and sometimes to the ther.

Carbonates and bicarbonates are entered in the same place in the ables, the latter preceded by bi. It may be useful to say that the atio of carbonate to bicarbonate for a given amount of the base found : For lime, 100:162.02; for magnesia, 84.36:146.38; for iron (FeO), 16:178.02; for soda, 106.10:168.12. In a rough way, there is half as nuch again when the compound is given as bicarbonate as when it is iven as carbonate.

WATERS OF THE GREAT LAKES SYSTEM.[1]

Constituent.	1. Manistee Lake.	2. Muskegon Lake.	3. Traverse Bay.	4. Detroit River.	5. Detroit River.
Al_2O_3	.....	.....	.....	.....	0.0105
$CaCO_3$	*5.898* .101	*4.882* .084	*3.412* .058	*3.144* .054	.033
CaP_2O_8	.....	.....	.....	.....	.0311
$CaSO_4$	Tr.	*1.660* .028	*2.736* .031	*.954* .011	
$(FeAl)_2O_3$	Tr.	*.029* .001	Tr.	Tr.	.....
$FeCO_3$	.....	.....	.....	.....	.00814
$MgCO_3$	*2.345* .040	*2.654* .046	*2.018* .034	*1.208* .021	.....
K_2SO_4	.....	.....	.....	.....	.00281
SiO_2	*.292* .005	*.292* .005	*.215* .004	*.330* .006	.005
(NaK)Cl	*5.100* .087	*1.02* .017	*.680* .012	*.900* .015	.....
$(NaK)_2CO_3$	*.147* .003	*.209* .004	*.764* .013	*.045* .001	.....
Na_2SO_4	.....	.....	.....	.....	.0075
Organic matter	.....	.....	*.467* .008	.....	.....
Total	*13.782* .236	*10.746* .185	*9.344* .160	*6.306* .108	.09807

[1] Analyses are given in grams per kilogram, or parts per thousand. Numbers in italic are quantities expressed in the units in which the analyses were originally published, usually, as in the first table *in grains per United States gallon.*

Constituent.	6. Detroit River (A).	7. Detroit River (B).	8. Detroit River (C).	9. Bay City (A).	10. Bay City (B).	11. Bay City (C).	12. Saginaw Bay.
CaO	0.0355	0.0360	0.0348	0.079072	0.116928	0.105952	0.031136
P_2O_5	0	Tr.	0	.....	.....	.....	.....
SO_3	.0056	.0060	.0056	.....	.....	.....	.....
MgO	.0121	.0127	.0123	.030558	.049874	.053333	.016432
SiO_2	.0066	.0062	.0089	.....	.....	.....	.....
Cl	.....	.....	.0075	.058	.265	.284	.010
Total	.1188	.1184	.1140	.....	.....	.....	.....

Analyses 1 to 4 were made by commercial chemists of the Dearborn Drug and Chemical Works, of Chicago. Their primary purpose was to determine quality as boiler waters; they were stated in grains per United States gallon; they did not aim at completeness, and no summation was given in the original analysis.

No. 1, of water from Manistee Lake, was made for Filer & Sons, August 31, 1897. The water was probably contaminated by the large salt works there.

No. 2, of water from Muskegon Lake, was made for the Electric Light Company, November 23, 1897.

No. 3, of water from Traverse Bay, was made for the electric light works of H. D. Campbell & Sons, August 31, 1897. Further analyses will be found in the Appendix (2A, 2B, 2C). It will be noticed, on comparing them with the deep-well water supply, analyses Nos. 56 and 57, that the bay water is considerably less hard. Of course it is more liable to typhoid contamination.

No. 4, of water from Detroit River, was made January 22, 1897, for the Schiller Corset Company.

No. 5 is an old analysis, made by Prof. S. H. Douglass in 1854, and cited in the biennial report of the State geologist, A. Winchell, in 1861, page 204. The total solids agree with other analyses, but the phosphates and sulphates are quite different, though some phosphorus is probably often overlooked.

Nos. 6 to 12 were made by Prof. A. B. Prescott, Nos. 6 to 8, of water from Detroit River, in conjunction with T. J. Wrampelmier, for the Detroit board of health (First Annual Report, 1882, pp. 229–238). Further analyses will be found in the Appendix (Nos. 5A, 6A, 7A).

No. 6 is of water from a West Fort street hydrant at Detroit; No. 7 of water from the pumping well, and No. 8 of water from the river at the inlet pipe of the Detroit pumping station.

Nos. 9 to 12 were published in a special report to the board of waterworks of Bay City, October 24, 1885, the waters of Nos. 9 to 11 being taken from manholes Nos. 4, 2, and 1, respectively, in the pipe leading from the pumping station on the bay shore to Essexville. One object of the investigation was to see if the water was contaminated in the transit by any waste of salt manufacture.

Sample No. 12 was taken about 2 miles north from the mouth of Kawkawlin River, and 1½ miles from the west shore of the bay, in water 6 feet deep, September 27. This also contained 0.04 per million parts of free ammonia and 0.15 of albuminoid; it reduced permanganate very slightly, was colorless and odorless, as were all the samples, but the residue blackened slightly on ignition.

Analyses of water from Saginaw Bay near Bay City.

	13.	14.	15.	16.	17.	18.
Ammonia free	0.00007	0.00016	0.00005	0.00007	0.00004	0.00008
Ammonia albuminoid	.00011	.00012	.00008	.00017	.00022	.00016
Permanganate reduced	2	1	4	7	8	3
Color	Colorless.	Colorless.	Nearly colorless.	Slight.	Perceptible.	Distinct.
Chlorine	.012	.010	.029	.072	.072	.039

	19.	20.	21.	22.	23.	24.
Ammonia free	0.00007	0.00004	0.00002	0.00003	0.00005	0.00004
Ammonia albuminoid	.00016	.00022	.00007	.00024	.00024	.00012
Permanganate reduced	6	2	6	3	7	1
Color	Distinct.	Slight.	Very slight.	Slight.	Distinct.	Colorless.
Chlorine	.235	.226	.221	.200	.061	.010

Besides analyses Nos. 9 to 12 and the Saginaw River analysis (No. 45) below, Professor Prescott made a number of tests for ammonia, free and albuminoid, and chlorine (analyses Nos. 13 to 24). Prescott pronounced the waters of analyses Nos. 12, 13, 14, 24, which are all taken from Saginaw Bay, more than a mile from the shore and in water over 10 feet deep, to be suitable for city use. Analyses Nos. 19 to 22, of water taken from the waterworks system, are not satisfactory, the organic matter being on the limit of safety, and the chlorine, which is probably not, however, of organic origin, far too high. These should be compared with analyses Nos. 32 and 33, of water from the same system, made by Prof. V. C. Vaughan. Samples Nos. 15, 16, 17, 18, and 23, taken from the bay nearer the pumping station and the shore, are not quite satisfactory, and though they contain less chlorine the quantity is still abnormally large, while Saginaw River water No. 45, West Bay City waterworks, is entirely unfit for use. The exact locations from which the waters of these analyses were taken are as follows:

No. 13, about 1 mile NNW. from the mouth of the Kawkawlin River, in water 11 feet deep, July 23, 1885.

No. 14, about 4 miles NE. from the mouth of the Saginaw River, in water 21 feet deep, July 24, 1885.

No. 15, about 3¼ miles E. from the mouth of the Saginaw River and 1 mile N. from the present inlet works, in water 10 feet deep, July 23, 1885.

No. 16, inlet cut of the present works at the outer end of breakwater, July 23, 1885.

No. 17, the inlet basin at the bay, at the outer end of the pipe leading to the pumping station, July 23, 1885.

No. 18, same point as sample No. 17, August 11, 1885; turned very black on ignition.

No. 19, well at pumping station, inner end of pipe leading from the bay, August 11, 1885.

No. 20, hydrant near the corner of Fourth and Water streets, August 14, 1885.

No. 21, hydrant near the corner of McGraw avenue and Harrison street, August 14, 1885.

No. 22, same point as sample No. 20, but when there was a large quantity of sediment from flushing the pipes; sample taken August 22, 1885.

No. 23, a point 3,000 feet NNE. from the present inlet basin, in water 7½ feet deep, September 25, 1885.

No. 24, a point 5,500 feet NNE, from the present inlet basin, in water 10½ feet deep, September 25, 1885; blackened slightly on ignition.

	25. Detroit.	26. Marine City.	27. Port Huron.	28. Port Huron.	29. Port Huron.	30. Alpena.	31. Wyandotte.	32. Bay City.	33. Bay City.
Result of inoculation	−	+	+	+	−	+	+	−	+
Number of bacteria in 72 hours	2	(a)	(a)	(a)	(a)	22	1,890	420	450
Nitrites	.....	Ft. tr.	.....	.....	.....	.....	0.0000082	.....	.....
Nitrates	.....	Tr.	Tr.	Tr.	Tr.	.....	.000653	.....	.....
Albuminoid ammonia	0.000102	0.00112	0.000120	0.000132	0.000126	0.00037	.00052	0.00048	0.00068
Free ammonia	.000016	.0001	.000009	.000007	.000006	.00048	.00008	.00034	.001
Permanganate reduced	.....	.....	.....	.....	.....	.008104	.032548	.063832	.106176
Chlorine as NaCl	.00115	.00990	.00830	.0090	.00825	.0066	.0495	.4257	.4653
Organic residue	.020	.110	.040	.070	.030	.025	.030	1.210	.980
Inorganic residue	.030	.043	.120	.150	.040	.162	.191	1.960	1.990
Total residue	.050	.153	.160	.220	.070	.187	.221	3.170	2.970
Hardness	.7°	4.°	2.°	2.1°	2.°	8.10°	7.°	15.°	15.5°
Sulphates	.....	.....	Tr.	Tr.	Ft. tr.	.....	.....	.....	.....

a Liquefaction.

Analyses 25 to 33 are sanitary analyses by Prof. V. C. Vaughan, made at Ann Arbor. The dates and the original numbers (in parentheses), the results of microscopic examination, etc., are as follows:

No. 25 (259), April 19, 1895, water said to be from the bay, i. e., the upper part of the Detroit River (?); reaction faintly alkaline; thi-

the regular separation of silica before the separation of alumina and ferric oxide take place.

Evaporation was carried on in broad, shallow, ½-liter porcelain dishes, covered with a funnel of special design with an incurved rim, made to set snugly (but unfortunately not air tight) upon the rim of the evaporating dish.

I say unfortunately not air tight, for Mallet has shown that the flame of the Bunsen burner in time produces quite appreciable amounts (when fine work is considered) of $(NH_4)_2SO_4$ and that unless the evaporating dish is kept tightly covered, danger of error from this cause is likely to occur. (See Mallet's Report on Water Analysis in the Report of National Board of Health, 1882, p. 194, where he shows that nitrogen determinations by Frankland's combustion process, as ordinarily conducted, give too high results from this cause.) Mention of this is made here only to indicate that this might possibly somewhat affect the determination of sulphuric acid.

To the nozzle of the funnel was attached a rubber tube connected with a water section pipe. This served to create a rarefaction above the evaporating water, thereby increasing the rate of evaporation and permitting the use of the lower temperature. Any steam failing to pass off through the pump because of condensation on sides of the funnel could not run back into the dish, but was caught by the incurved rim of the funnel. Extraneous particles of dust, etc., were also thus excluded. When total solids were to be estimated evaporation was in no case continued to dryness; but the liquid concentrated to about 200 cubic centimeters was carefully transferred in portions to a large platinum evaporating dish, with subsequent thorough rinsing with distilled water, the whole evaporated to dryness, dried in the air bath at 100° C. for three hours, cooled in a desiccator over sulphuric acid, and weighed for total solids. Five such determinations were made. The residue was ignited at low red heat for about two hours to constant weight, cooled, and weighed as total inorganic solids. In a few cases this latter residue was treated with $(NH_4)_2CO_3$ in solution, reheated, and weighed again; but the increase averaging only 0.6 milligrams per liter, this operation was subsequently neglected, although account was taken of it in final results.

One and one-half liters were concentrated by evaporation, transferred to platinum dish and evaporated to dryness, weighed, ignited, and weighed again, as described above, for total solids and inorganic solids. The residue was then examined qualitatively, by the usual methods, with good tests resulting for Al, Fe, Ca, Sr, and Mg (rather fainter test). The flame test showed Na but no K, which occasioned some surprise. Through the kindness of Prof. L. W. Langley, the aid of his spectroscope and his personal assistance were secured to identify any of the rarer metals that might be present—it being thought that Li at least might be present; but nothing was found that had not been already identified, except that faint, evanescent flashes of K were seen.

Thinking that previous estimation of total solids and consequent protracted ignition of this sample might possibly have affected the spectroscopic result somewhat, two or three fresh trials were made on concentrated solutions before full evaporation, but with no different results.

Pb was tested for in a large 8-inch test tube full of the sample (after acidulation with 1 to 2 drops of acetic acid) by addition of a drop of solution of $K_2Cr_2O_7$ with no result. Cu was tested for in a similar manner with 1 to 2 drops of solution of K_4FeCy_6 and allowed to stand over night, when a very faint green or greenish-blue tint was apparent, evidently due to Fe only. Mn was tested for by PbO_2 and HNO (in concentrated solution), with no result.

Fair tests for HCl and H_2SO_4 were obtained. Cl water and CS_2 showed scarcely definable traces of Br, and $(NH_4)_2MO_4$ in HNO_3 solution gave no distinguishable trace of H_3PO_4, and no I nor TiO_2 was found, all, of course, worked for from concentrated solutions. Most, if not all, nitrates and nitrites would have been destroyed

by ignition in presence of organic matter and were therefore not looked for at this point. (See under quantitative work.) In reference to the comparatively few elements found, it is to be remembered that different results might reasonably have been expected could larger quantities of the water have been spared for such work.

For quantitative work in each case 3 liters were taken and evaporated to dryness, after acidulation with HCl and SiO_2, separated in the usual way, with care against high heating and consequent danger of partial reunion of separated SiO_2 with the bases. Fe_2O_3 and Al_2O_3 were precipitated from the filtrate by boiling with fair excess of HH_4OH (in presence of NH_4Cl) and the united oxides weighed. The Fe was subsequently subtracted, after volumetric estimation by Oudemans' method (i. e., by $\frac{n}{10}$ $Na_2S_2O_3$ in presence of $CuSO_4$, with a drop of KCyS as indicator) and also by the excellent method described in Professor Cheever's Laboratory Notes (Part I, p. 27, and Part II, p. 6), by reducing Fe_2Cl_6 to $FeCl_2$ in boiling HCl solution, by means of $SnCl_2$ carefully added from burette, and any excess of $SnCl_2$ taken up with $HgCl_2$ and the $FeCl_2$ titrated with $\frac{n}{10}$ $K_2Cr_2O_7$. Al and Fe were also directly separated by pouring into boiling KOH in excess, after the method of Fresenius.

Ca and Sr were precipitated together from the filtrate from Fe and Al by addition of $(NH_4)_2C_2O_4$ and $(NH_4)_2CO_3$, the combined precipitates carefully heated in platinum crucible by playing back and forth underneath a small flame and carefully noting the change in color of the precipitates. After thus working to constant weight, the residue was tested with a bit of moistened turmeric paper to see that no reduction to oxides had occurred.

The Ca and Sr were then separated by the method of H. Rose (given by Fresenius) by precipitating with $(NH_4)_2SO_4$, filtering hot, and continued washing with concentrated solution of $(NH_4)_2SO_4$ until filtrate showed no test with $(NH_4)_2C_2O_4$. This filtrate after concentration was reworked for Ca by reprecipitation with $(NH_4)_2C_2O_4$. The Sr was treated similarly to $BaSO_4$ and weighed as $SrSO_4$. After weighing Ca as $CaCO_3$, in addition to the precautions mentioned above, the precipitate was in each case dissolved in excess of boiling $\frac{n}{10}$ H_2SO_4, to expel CO_2, and the excess of H_2SO_4 neutralized by $\frac{n}{r}$ KOH, with phenol phthalein as indicator, and Ca recalculated as a check.

Mg was precipitated from the filtrate from Ca and Sr in the usual way, as NH_4MgPO_4 and weighed as $Mg_2P_2O_7$. Double precipitation of the Ca and Sr was performed in each case to insure separation of Mg.

One liter was taken in each case, and the Na separated and weighed as NaCl, and then dissolved in water, and the Cl estimated with standard solution $AgNO_3$, and Na recalculated. The method for separation followed is the one used for separation of K, recommended by the Association of Official Agricultural Chemists, 1886 (Dept. Agriculture, Div. Chem., Bull. No. 12). The principle is familiar, i. e., the removal of bases and H_2SO_4 by boiling with $Ba(OH)_2$ and a little $BaCl_2$, filtering, and removing Ca by $(NH_4)_2C_2O_4$ and the excess of $BaCl_2$ by $(NH_4)_2CO_3$, the evaporated residue ignited, dissolved, filtered, acidulated with a drop of HCl, ignited, and weighed as NaCl, and treated as above. Great care and practice seem essential to obtain anything like closely concordant results. In the following table, because of considerable divergence in the gravimetric results, only the volumetric results are considered, the average of all being taken. That appreciable quantities of NaCl may be lost by several minutes' ignition at red heat is shown by Fresenius's experiments.

H_2SO_4. The precipitate in the preceding results for Na (thrown down by $Ba(OH)_2$ and $BaCl_2$) was treated with HCl in excess in hot solution, thoroughly washed and treated as usual for $BaSO_4$.

HCl. One-half to one-fourth liter was concentrated to about 100 cubic centimeters and the Cl estimated by $AgNO_3$, with K_2CrO_4 as indicator. Two strengths of the solu-

tion of $AgNO_3$ were tried; No. 1, 1 cubic centimeter of the solution = 1 milligram Cl; and No. 2, 1 cubic centimeter of the solution = 0.1 milligram Cl.

Combined CO_2. 250 cubic centimeters was concentrated to about 100 cubic centimeters, and moderate excesses of $\frac{n}{10}$ H_2SO_4 run in from burette, and the solution was boiled to free it from CO_2. Then excess of acid was neutralized with $\frac{n}{10}$ KOH with phenol phthalein as indicator. Fresenius recommends HNO_3 with tincture cochineal indicator; but probably through inexperience in its use the results were not thought to be so satisfactory as the method mentioned above. I am aware that the method adopted is open to very serious objections, not the least of which is the danger of loss of HCl and HNO_3 on boiling to expel CO_2. It was attempted to avoid this and the consequent higher results as much as possible by working to get the approximate point with the standard alkali with turmeric indicator before boiling, and then finishing in the usual way. It will be observed that if all the HCl and HNO_3 were lost it would increase the reading for CO_2 about 1.7 milligrams per liter. It would, on the whole, perhaps have been better to have used the theoretically much better method of liberating the CO_2 by acidulation in closed flasks and absorbing the CO_2 in KOH bulbs or standard $Ba(OH)_2$ solution by Pettenkofer's method. This was not tried, however, from fear of loss in transferring from evaporating dish to flask.

The specific gravity of the dish of water was taken by the spherical specific-gravity bottle used in this laboratory, and both distilled water and the sample were brought to 27° C. before filling the bottle.

In the following table all the results are the average of results obtained and in no case the result of a single estimation.

All results are given in parts per million; or, what is the same thing, milligrams per liter.

34. Lake Superior water.

Specific gravity (at 27° C)	1.0004
Total residue	69.97
Inorganic residue	57.61
Loss on ignition	12.36
Organic determinations:	
Free ammonia	.061
Albuminoid ammonia	.12
Oxygen consumed	1.77
Hardness:	
Temporary	*a* 48.57
Permanent	*a* 38.28

Inorganic constituents:

Al_2O_3	= 0.90	Al	= .48
Fe_2O_3	= 0.99	Fe	.69
CaO	= 17.98	Ca	= 12.80
SrO	1.60	Sr	1.34
MgO	= 4.63	Mg	= 2.78
Na_2O	= 4.29	Na	= 3.18
K_2O	Very faint trace.	K	Very faint trace.
SO_3	= 3.11	SO_4	= 3.73
SiO_2	6.73	SiO_3	= 8.53
B_2	Trace.	B_2	Trace.
Cl	= 2.43	Cl	= 2.43
N_2O_4	= 0.00	.....	
N_2O_5	= 0.67	N_2O_6	.77
CO_2	16.30	CO_3	= 22.23
			58.96

The purpose of this second set of figures, with bases reported as free elements and the acids as acid radicals, is that the total results thus obtained may be compared with the inorganic residue.

a In parts per million, not in degrees.

WATERS OF RIVERS AND SMALL LAKES.

Constituent.	35. Battle Creek.	36. Owosso.	37. Jackson.	38. Ann Arbor.	39. Shiawassee.	40. Cass.	41. Chippewa.
$CaCO_3$	*3.679* / .063	*6.041* / .103	*8.652* / .148	*7.495* / .128	0.1090	0.1130	0.1314
$CaSO_4$	*1.494* / .025	*1.394* / .024	*2.490* / .043	*5.810* / .099	.....	.....	.0316
$(AlFe)_2O_3$	Tr.	*.058* / .001	Tr.	Tr.	.0061	.0070	.0094
$MgCO_3$	*2.853* / .049	*5.015* / .086	*4.264* / .073	*4.866* / .083	.1789	.03322	.....
$MgSO_4$	.....	.....	.....	.....	.0369	.0309	.....
$(NaK)_2CO_3$	*1.770* / .030	*1.228* / .021	*.376* / .006	*1.453* / .025	.....	.....	.....
$(NaK)Cl$	*1.020* / .017	*1.360* / .023	*1.200* / .021	*.900* / .015	.0231	.02405	.0504
SiO_2	*.380* / .007	*.438* / .007	*.537* / .009	*1.343* / .023	.0691	.0470	.0140
P_2O_5	.....	.....	.....	.....	Tr.	.....	.....
Ammonia, free	.....	.....	.....	.....	.00011	.00015	.....
Ammonia albuminoid	.....	.....	.....	.....	.00054	.00054	.....
Organic and volatile.	*.818* / .014	*.818* / .014	..... / Tr.	*.818* / .014	.....	.....	.....
Total	*12.014* / .205	*16.352* / .279	*17.519* / .300	*22.685* / .387	*a* .423	*a* .2552	.2360
Hardness	.....	.....	.....	.....	16.6°	7.5°	.....
Chlorine	.....	.....	.....	.....	.0140	.0146	.....

a Inorganic.

Constituent.	42. Saginaw W.	43. Saginaw E.	44. Tittabawassee.	45. Bay City.	Constituent.	42. Saginaw W.	43. Saginaw E.	44. Tittabawassee.	45. Bay City.
$CaCO_3$	0.134	0.11057	0.138	.....	Ammonia, free	0.00048	0.000104	0.000256	Tr.
CaO	.....	.....	.....	0.78624	Ammonia albuminoid	.00043	.000350	.000440	0.00025
$CaSO_4$	.....	.01788	.04008	.....	Total inorganic	.32686	.34509	.42438	.....
$(FeAl)_2O_3$	.007	.0611	.0843	.....	Hardness	10.5°	6.4°	8.0°	.....
$MgCO_3$	.04678	.....	.....	.....	Chlorine	.0494	.0372	.027	.072
MgO	.....	.....	.....	.36468					
$MgSO_4$	.02968	.01944	.0084	.....					
SiO_2	.028	.078	.1092	.....					
$NaCl$	.0814	.0581	.0444	.....					
P_2O_5	Tr.	Tr.	Tr.	.....					

Analyses 35A and 35B in the Appendix are of water from Boardman River near Traverse City, the former made by R. C. Kedzie and the latter by the Dearborn Drug and Chemical Works, and they agree in indicating a relatively soft water.

Analyses Nos. 35 to 38 are boiler-water analyses made by the Dearborn Drug and Chemical Works, of Chicago.

No. 35 is of the Battle Creek city water supply, which is usually obtained from Lake Goguac, and was made for the Advance Thresher *Company on August 6, 1897.*

No. 36 is of water from the Shiawassee River at Owosso, and was made for the Estey Manufacturing Company, factory A, on October 30, 1897; there is less matter in solution at Owosso than farther down the river, as shown by No. 39.

No. 37 is of water from the Grand River at Jackson, and was made for the Withington-Cooley Manufacturing Company on February 11, 1897.

No. 38 is of water from the creek at Ann Arbor (? the Huron River), and was made for the Ann Arbor Electric Company.

Analyses Nos. 39, 40, 42, 43, and 44 were made by G. A. Kirchmaier for the board of water commissioners of the city of Saginaw, and were published in the supplement to the annual report of that board for 1892, pages 31–33.

No. 39 is of water from the Shiawassee River.

No. 40 is of water from the Cass River.

No. 41 was made by J. E. Graves, of the Dow Chemical Company; the sample was taken from the Midland water supply (Chippewa River) on July 27, 1896. This analysis is very like analysis No. 44, of water from the Tittabawassee River.

No. 42 is of water from the west-side pumping station, Saginaw, and its thoroughly unsatisfactory condition will be treated in a later paper. The chlorine, 0.0494, is the highest of the set.

No. 43 is of water from the east-side pumping station, Saginaw.

Analyses 43A to 43D, made by H. and W. Heim for S. G. Higgins, show the composition of Saginaw River water at various places and the increase in NaCl and organic residue. The impurities in the water increase downstream. On the whole the magnesia and lime also increase, although quite irregularly.

No. 44 is of water from the Tittabawassee River.

No. 45 is of water from the Saginaw River at Bay City, and was made by Prof. A. B. Prescott at the same time as the analyses of the Bay City supply (Nos. 13 to 24), namely in July, 1885. The sudden increase in CaO and chlorides together is due to contamination by the waste bitterns of salt manufacture. The Marshall sandstone yields brines with considerable calcium chloride. The amount of lime carbonate does not increase with the general increase in mineral matter, but shows a strong tendency to stick at about one-tenth of an ounce per cubic foot, which is enough to indicate the presence of bicarbonates. Sulphates of lime are almost invariably present, though the sulphate is sometimes returned only as sulphate of magnesia. Throughout the coal basin and southwest of it this salt is very prevalent both in wells and streams.

Ten analyses, by college students, of water from a brook near the Agricultural College (analysis No. 36A in the Appendix) give, as an average result, a much softer water than most of the stream waters analyzed. The sample was probably taken after a rain.

A series of twenty-two analyses of waters from marl-depositing and *other lakes*, wells, and outlet streams, collected by W. J. Hale, near

Cloverdale, Barry County, were made by A. N. Clark. The $MgCO_3$ is usually between 0.065 and 0.085 parts per thousand, the extremes being 0.203 and trace. The amount of $CaCO_3$ is more variable, being as high as 0.217 and never less than 0.030. As much as 0.066 of free CO_2 was sometimes found, supposed to be in addition to that present as bicarbonate.

	46. Cadillac.	47. Battle Creek.	48. Mancelona.	49. St. Louis.	50. Wayne.	51. Wayne.
Result of inoculation	–	--	+	.....	–	–
Number of bacteria in 24 hours	100	Countless.	76	1,088	.....	.....
Nitrites	.....	.....	.....	.....	.....	0.000026
Nitrates	Tr.	.....	Tr.	.....	.....	.000016
Albuminoid ammonia	0.0000528	0.00022	0.0000533	0.00032	.....	.....
Free ammonia	Tr.	.00015	.000013	.000046	.....	.....
Permanganate reduced	.....	.....	26	.....	.....	.....
Chlorine as NaCl	.00066	.028	.0083	.....	.....	.033
Organic residue	.040	.080	.288	.....	.....	.....
Inorganic residue	.060	.100	.246	.....	.....	.....
Total residue	.100	.180	.534	.....	.....	.....
Hardness	4.0°	10.2°	14.3°	14.4°	.....	.....

Analyses Nos. 46 to 51 are sanitary analyses by Prof. V. C. Vaughan, of Ann Arbor, and are in general subject to the same remarks and interpretation as the others (see p. 44).

No. 46 (193), water from Clam Lake near Cadillac, July 29, 1893; brownish, musty; microscope shows vegetable fibers and a few forms of animal life.

No 47 (294), water from a Battle Creek hydrant; reacts alkaline, and under the microscope shows diatoms and inorganic matter.

No. 48 (345), water from a lake in Mancelona, T. 29 N., R. 6 W., November 17, 1896. The water is reddish brown in color, has a marked odor and acid relation, and under the microscope shows the presence of considerable vegetable matter.

No. 49 (35), water from the Pine River at St. Louis; contained no pathogenic germs.

No. 50 (372), water described as "cloudy, stinking," and No. 51 (373), were tests of Huron River water and the overflow of the settling basins of the Wayne County poorhouse, October 25, 1897.

WATERS FROM WELLS IN THE UNCONSOLIDATED DEPOSITS (PLEISTOCENE) AND FROM SPRINGS.

This group includes those waters which have penetrated in their circulation but a little way under ground. All the common dug wells belong to this class, and probably a very large portion of the waters of the unclassified analyses given in a later section.

The Michigan board of health has issued a plate showing the relation that the *depth of water* in wells bears to the prevalence of typhoid

fever during the different months of the year. From April to June the water in the wells is, on an average, within 200 inches of the surface of the ground, and typhoid fever is least common. By October the average water level has fallen over 30 inches, and typhoid fever is most prevalent.

I begin with analyses which show only a small proportion of mineral matter—considerably less than 1 ounce to the cubic foot—and which may be classed as pure drinking waters, soft or slightly hard. Some of these waters are reputed to have curative powers, but none have any mineral taste, and it is probable, as the proprietor of the Ponce de Leon spring remarks, that their virtue lies mainly in their purity.

As the percentage of mineral matter increases the waters, almost without exception, become hard, and are comparable to the river waters in lime (one-tenth to two-tenths of an ounce per cubic foot), but contain more iron and silica than the latter. In these more mineralized waters some of the apparent variety in the chemical combinations seems to be due to the fancy of the chemist—for instance, the presence of sulphate of potash in some and of carbonate of potash in others of the Benton Harbor Eastman springs. Analyses by Duffield are particularly unusual in the combinations assumed.

It will be noticed on comparing the deeper and shallower wells at Traverse City (Nos. 56 and 57), at Holland (Nos. 147 and 159), and at Ypsilanti (Nos. 70 and 71), that no tendency is seen toward a greater mineralization with depth—the rule which prevails among wells in the rock. It is probable that a careful study would show a zone close to the surface, a foot to a few feet down, from which the lime had been removed by leaching, for at Mecosta and other places I have found very shallow, easily exhausted wells used for laundry purposes. Then just below this would be a belt in which the lime and iron had been deposited as a cement in extra richness, while lower down would be found waters of the unaltered drift.

Finally, there is a group of waters (analyses Nos. 73 to 80) which are strongly sulphated, and, with the exception of the Detroit well, come from the same region, a region in which gypsum bowlders have been found scattered in the drift. The exception (No. 76) has more salt than the others, and is more like a weak brine. Near Marine City, on the farm of Mrs. E. Gardner, there is a well of which no complete analysis of the water is available, but which is said to contain, out of a thousand grains per gallon solids, more than half $MgSO_4$ (Epsom salts). Such sulphated waters may be due either to the solution of gypsum or to the production of sulphuric acid or sulphates by the decomposition of pyrite, which is abundant in the drift and in the rock, and their subsequent reaction upon carbonates or chlorides.

The wholesomeness of these sulphated waters depends largely on the individual constitution. Professor Kedzie condemned waters from Mount Pleasant as too high in sulphates (and I should agree with him) *which Professor* Vaughan passed as good because free from dangerous

organic contamination. I find, however, that in such regions some doctors complain of the prevalence of indigestion, constipation, and calculi.

Belonging to the group of highly sulphated mineralized waters from the drift of the center of the State are probably some of the analyses by Kedzie of waters around Saginaw (Nos. 108 to 110), but as some of those wells penetrate a few feet into the top sandstone, and as others draw their water from a bed immediately overlying it, I have deemed it better to treat them in the next section, since it is not certain how far wells in the drift only are mineralized under that city. For example, the well at 905 Court street, East Saginaw, about 80 feet deep, gave in the analysis of Dr. Small only 6.5 grains to 1 liter, or 0.421 part to a thousand solids, with a faint Cl reaction. The two Midland waters (analyses Nos. 75 and 77) are in practically the same class.

Constituent.	52. Ponce de Leon spring.	53. Harbor Springs.	54. Greenville.	55. Ann Arbor (University).	56. Traverse City High School.	57. Traverse City (Asylum).	58. Pontiac.
Al_2O_3							*0.0806* .0014
$CaCO_3$	*7.2* .12312	*8.50* .121	*9.63* .136	0.178	0.128	*9.758* .167	*9.6807* .1660
$CaSO_4$	Tr.		0		.002	*1.328* .026	
Fe_2O_3		*.50* .007			.003	*.298* .005	*.5025* .0086
$FeCO_3$				.0029			
Li_2CO_3							*.0200* .0003
$MgCO_3$		*1.50* .021	*3.175* .045	.06958	.034	*4.001* .068	*3.9159* .0672
KCl							*.06990* .0012
K_2SO_4				.00678			
SiO_2		*1.00* .014		.0073	.006	*1.997* .034	*.4082* .0070
NaCl	Tr.	*.50* .007	0	.00448	.006	Tr.	*.3090* .0053
Na_2CO_3				.00152		*a .602* .010	*.2916* .0050
Na_2SO_4				.00507			*.2799* .0048
Nitric acid			*.207*				
Free CO_2			.003	.0015598			
Organic	*1.75* .030	*1.50* .021	0	.0023	.014		*c .9244* .0158
Total	*8.959* .153564	*13.00* .183	*13.25* .189	.28963	.193	*17.987* .307	*16.4827* .2826
Total hardness	7.2°	11.°			12.°		
Permanent hardness		5.°			6.°		
Free ammonia			.000052		.00015		
Albuminoid ammonia			.000003		.00008		

a CNa or K. *b* Oxygen reduced by permanganate. *c* Loss.

Constituent.	59. "King David," Benton Harbor.	60. "Silver Queen," Benton Harbor.	61. "Saul," Benton Harbor.	62. "Colonel's Own," Benton Harbor.	63. Springs, Petoskey.	64. "Park," Alma.	65. "Nochemo," Reed City.
Al_2O_3	*0.117* .0020						0.001
$CaCO_3$	bi. *8.124* .1390	bi. *6.800* .1165	bi. *7.797* .1336	bi. *8.835* .1520	*12.32* .176	0.188	bi. .203
Fe_2O_3				*.234* (*a*). 00402	*.14* .002		0.03
Fe_2CO_3	bi. *1.298* .0223		bi. *1.049* .018			.106	.002
$MgCO_3$	bi. *3.532* .0605	bi. *3.225* .0553	bi. *6.144* .1052	bi. *6.296* .1078	*2.80* .040	.041	bi. .110
P_2O_5	Well-marked traces.						.0003
Mn	...Do...						
K_2CO_3		bi. *1.074* .0184		bi. *1.559* .0267			
$MgSO_4$						.020	
K_2SO_4	*.145* .00244	Tr.	*.083* .00145	Tr.			Tr.
SiO_2	*.583* .0100	*.117* .0020	*.350* .006	*.117* .0020	*.70* .01	.017	.014
NaCl	*.119* .00205	*.096* .001645	*.095* .00163	*.119* .0020	*.49* .007	.007	.014
$NaCO_3$	bi. *.676* .01168	bi. *1.364* .0234	bi. *1.021* .0176	bi. *.835* .0188			bi. .033
Na_2SO_4			*.110* .00199				
Organic					*2.50* .03		
Total	*14.592* .2502	*12.676* .2004	*16.649* .2854	*18.036* .3096	*18.55* .265	.178	.078
CO_2 (*a*)	36.38	35.46	37.21	38.96		.027	

Constituent.	66. Ann Arbor (S. Mann).	67. Wayland (spring).	68. Otsego.	69. Albion (Warner's spring).	70. Ypsilanti (waterworks).	71. Ypsilanti (well).	72. Hubbardston (magnetic spring).
Al_2O_3				0.004		Tr.	
$CaCO_3$	0.228	*7.50* .107	bi. 0.244	bi. .290	0.289	*9.100* .156	bi. 0.4[illegible]
$CaSO_4$		*3.20* .046	.011	.058	.039	*12.948* .223	
Fe_2O_3		0	.036		.021	Tr.	.0[illegible]5
$FeCO_3$	.00468			bi. .029			
LiCl					Tr.		
$MgCO_3$	.08936	*.520* .074	bi. .026	bi. .080	.100	*6.350* .109	bi. .187
K_2SO_4	.00531		.020	.006			

a + Al_2O_3.

Constituent.	66. Ann Arbor (S. Mann).	67. Wayland (spring).	68. Otsego.	69. Albion (Warner's spring).	70. Ypsilanti (water-works).	71. Ypsilanti (well).	72. Hubbardston (magnetic spring).
SiO_2			0.048	0.003	0.014	*1.139* / .018	0.004
H_2SiO_3	0.012						
NaCl	.00488	*0.65* / .009	.028	.021	.035	*3.600* / .062	
Na_2CO_3	.00042	*1.50* / .021				*1.056* / .017	
Na_2SO_4	.00971			.036			
NaI	Tr.						
Nitrates					Tr.		
Volatile at red heat	.025	*8.00* / .114		Loss. / .017	.071	*.818* / .014	
Total	.37936	*27.000* / .386	.449	.546	.570	*35.04* / .509	.596
Ammonia free					.00003		
CO_2	.285		8 cu. in.				
Ammonia albuminoid					.00002		

Constituent.	73. Mount Pleasant (water-works).	74. Mount Pleasant (water-works).	75. Midland (Reardon).	76. Detroit (Amos T. Hall).	77. Midland (magnetic spring).	78. St. Louis.
$Al_2O_3P_2O_5$					0.025	
$CaSiO_3$						0.096
$CaCO_3$	(!)	0.173	bi. 0.038	0.3919		bi. .991
$CaCl_2$					.089	
$CaSo_4$	0.620	1.044	.0443	.2826	.064	.950
$FeCO_3$				.0102		bi. .017
$MgCO_3$	.120	.067				bi. .250
MgCl				.3476	.031	
$MgSO_4$			.0560			
KCl				.1100		
K_2SO_4				.1045	1.174	
H_2SiO_3			.054			
SiO_2				.0237	.042	.041
NaCl		.086	1.155	.7252	.467	Tr.
$NaCO_3$						bi. 1.520
$NaSO_4$	.018				.315	
Loss at red heat	.100	.024			.046	.029
Organic					.035	
Total	1.130	1.580	1.416	1.9957	2.288	3.895
Nitrites	Strong.	Distinct.				
Nitrates		Strong.				
Temporary hardness	8.°					
Permanent hardness	30.°					
CO_2						.069
Ammonia free	.00008	.008				
Ammonia albuminoid	.00002	.00015				
H_2S						Tr.

	79. Mount Pleasant (test well).	80. Mount Pleasant (test well).		79. Mount Pleasant (test well).	80. Mount Pleasant (test well).
Result of inoculation.	—	—	Chlorine as NaCl	.1815	.188
Number of bacteria in 72 hours	425	120	Organic residue	.470	.440
Nitrites	Large.	Very slight trace.	Inorganic residue	1.676	1.852
Nitrates	Tr.	Tr.	Total residue	2.146	2.292
Albuminoid ammonia	0.0000213	0.000072	Hardness	2.4°(?)	2.6°(?)
Free ammonia	.00012	.000043	Sulphates	Large.	Large.
Permanganate reduced	0.002	0.002			

No. 52 is of water from the Ponce de Leon spring, Grand Rapids, John DeBoe, analyst; bottled and used commercially since 1848; has no color, taste, odor, or sediment; specific weight at 59° F., 1.00465; found under 22 feet of clay; contains no nitrites; 0.000422 (0.0246) nitrates; 0.000015 (0.00087) free ammonia; and 0.000022 (0.00128) albuminoid ammonia. (For further notes and record of temperatures for different months in the year, see a later paper.)

No. 53, F. S. Kedzie, analyst for E. Shay & Son; water from 320-foot well at Harbor Springs. (See description in a later paper.)

No. 54 is of water from Greenville, February, 1888; furnished by city clerk. Oxygen reduced by permanganate 0.0003.

No. 55, Ann Arbor, water from well on north side of campus, 70 feet 8 inches deep; T. C. McNeill, analyst; temperature 50°; biennial report of State geologist (Michigan), 1861, page 203.

No. 56, F. S. Kedzie, analyst; nitrates, a slight trace; nitrites, none; water colorless, odorless, tasteless, of excellent quality; compare with analysis No. 3. This analysis is cited in Rafter's report to the city council of Traverse City as from Park Place Hotel. A full description of the numerous deep-flowing wells of Traverse City, of which this is an example, will be found in a later paper.

No. 57, Dearborn Drug and Chemical Works, analysts; primarily a boiler-water analysis; Na and K, Fe_2 and Al_2 included together. Well deepened since analysis was made. (See description in later paper.) The city is not supplied from these wells, the water being too hard, but from the bay (Nos. 2A, 2B, 2C, and 3).

No. 58, J. E. Clark, analyst; Welcome Island lithia water, 3 miles north of Pontiac, in the center of Lake Angelus.

No. 58A, an analysis of water from the Mount Clemens Pagoda springs; analysis of a much-used similar water will be found in the Appendix; C. G. Wheeler, analyst; temperature, 52°.

Nos. 59 to 62 are of waters from four out of the thirty or more springs of H. E. Eastman, 1 and 2 miles southeast of Benton Harbor; Professor Haines, analyst. The more mineralized waters, with the greater spe-

cific weight, seem to have a higher temperature and perhaps draw from a deeper layer, as follows:

No. 59, water from King David spring, Benton Harbor; temperature, 50° F.; specific weight, 1.000.

No. 60, water from Silver Queen spring, Benton Harbor; temperature, 50° F.; specific weight, 1.000125.

No. 61, water from Saul spring, Benton Harbor; temperature, 51° F.; specific weight, 1.00025.

No. 62, water from Colonel's Own spring, Benton Harbor; temperature, 51° F.; specific weight, 1.00025.

No. 63, water from Petoskey springs, F. S. Kedzie, analyst; 12° total hardness, 2° permanent hardness. Compare the analysis of water from the deep well (No. 294) in the Dundee limestone.

No. 64, water from Alma, C. A. Davis, analyst; originally stated in grains per United States gallon for the Alma Sanitarium. (See fig. 3, and compare descriptions and tests of waters from Alma wells in a later paper.) Temperature, 48.2° F.; reaction neutral or slightly alkaline.

No. 65, water from Nochemo spring; R. Fischer and A. B. Prescott, analysts; original statement in grains per United States gallon. Water bottled and sold is from flowing driven wells in a river bottom; the yellow of a chalybeate water is very apparent about them. The region is said to be an old deer-lick. (Compare analysis No. 83.)

No. 66, water from spring on land of Solomon Mann; T. C. McNeill, analyst; temperature, 50° F.; specific gravity, 1.001. Basis of sanitarium for several years. Biennial report of the State geologist (Michigan), 1861, page 204; Winchell, Geology of Washtenaw County (History of Washtenaw County), 1881, page 14. The CO_2 is partially free and partially combined acid. The water from Mount Clemens Pagoda springs (No. 58A) is similar.

No. 67, F. S. Kedzie, analyst; Wayland spring water. There are many flowing wells in Wayland, but only one is a rock well.

No. 68, cited by A. C. Peale, Bulletin U. S. Geological Survey No. 32; R. S. Kedzie, analyst. Water contains a trace of H_2S and 8 cubic inches CO_2 per gallon, and is from a rock well; the amount of potash is abnormal and reminds one of the Midland analyses.

No. 69, Warner's spring, Albion; D. Fall, analyst; cited by Peale, Bulletin U. S. Geological Survey No. 32, from Report State Board of Health, 1875, page 89; from flowing springs south of Lake Shore and Michigan Southern Railroad.

No. 70, F. S. Kedzie, analyst; water from Ypsilanti city waterworks; quality excellent. (See fig. 2.)

No. 71, 18-foot well; Dearborn Drug and Chemical Company, analysts for the Ypsilanti Electric Company; a boiler-water analysis, originally stated in grains per United States gallon.

No. 72, P. (? S.) H. Douglass, analyst; cited by Peale, Bulletin U. S. Geological Survey No. 32.

well), if it is the one of which Mr. Lincoln has furnished a record, is in the Pleistocene, but if not, as the drift is thick over all the region and as I am informed that rock has not been struck, it is probably a drift water, although it should perhaps have been included here in the unclassified section, rather than as analysis No. 72. The Lansing magnetic (Michigan Congress) well shows by its depth that it goes through the Marshall. It is plugged part way down. The temperature (53.5° F.) being not more than 7° above the mean annual temperature of the place, indicates that the main flow is from the same horizon as the deep Agricultural College well, i. e., from the Marshall, and the analyses (Nos. 241 and 242) show, as I have likewise been informed, that the upper calcic waters are not cased out. The Leslie magnetic well is almost certainly from the Coal Measures, though we have placed the analysis near those furnished by Prof. F. S. Kedzie below (No. 228). The Midland magnetic well (analysis No. 77) has been placed for comparison beside No. 78. Its temperature indicates that its depth is no greater than that of No. 78, but the analysis needs verification, and it may be merely an erroneous form of analysis 249, which water is from the Coal Measures. We have no analysis of the water from the Arcade Building mineral well at Grand Rapids, unless some of the uncertain analyses of Vaughan or Kedzie refer to it. The Moorman well (analyses Nos. 304 and 305) is, as is obvious from the description below, from the temperature (57.5° F.) of the water, and from the section shown in fig. 2, chiefly from the Helderberg limestone. Owen's mineral well (56.6° F.) and the Ypsilanti mineral well (58.1° F.) are similar. The Mount Clemens springs are from the same horizons. The Ogemaw mineral springs are in all probability from the drift and similar to those around Rose City. The Otsego mineral springs (analysis No. 68) appear to be from the drift. The Owosso spring analysis is most likely of water from one of the wells into the upper Coal Measures. Its source is, however, so uncertain that it is given below in this section (analysis No. 227). The Riverside magnetic mineral springs (Springwell's Fort) in Detroit are from the Dundee and the upper Monroe, as the temperature (50° F.) shows, and are described in the appropriate place. The St. Clair spring belongs to the same family. (See pp. 77, 78.) The St. Louis magnetic spring analysis (No. 78) is of water from a deep drift well within the coal basin. The Springlake magnetic well analysis (No. 265) belongs with the analyses of water from the Fruitport and Grand Haven wells, as all draw from the Marshall (Nos. 264 to 266). The Shawnee mineral springs probably derive their supply from the Helderberg or the immediately overlying drift, but the waters are not analyzed. The temperature (47° to 49°) is practically the mean annual temperature of the place, which shows that the wells are not deep.

Sulphur springs are very abundant in that region and apparently *derive their* water from the Dundee limestones, in some cases, perhaps, *from the Monroe.* (Compare analyses Nos. 294 to 302.)

picion than rock wells, it is obvious that most of these analyzed waters of uncertain origin belong to the group of the preceding section, waters more or less from the drift; this is the excuse for introducing these analyses here rather than later. Whenever one of these analyses seems to indicate a water not from the Pleistocene, attention is called to the fact.

Peale, in Bulletin U. S. Geological Survey No. 32, does not give the geological source of the waters analyzed. Most of them, however, I have been able to classify by determining their geological source in such ways as the following examples will indicate: The Alpena magnetic well is certainly one of the deep borings into the so-called Dundee limestone, as the temperature (52° F.) of the water, which is 10° higher than the mean annual temperature of Alpena (42°), and its sulphureted character indicate, and I have placed it accordingly. (Analysis No. 297.) The Berrien springs are uncertain, and no analysis is given. Butterworth's magnetic spring, or Grand Rapids magnetic, as I learn from Mr. Powers,[1] is a well into the Marshall, with mineral additions from the Michigan series; or, as Mr. Powers says, his own well (the Arcade) draws from the lower 18 feet of the Marshall sandstone, which is about 100 feet thick, and has less $CaCl_2$ than Butterworth's, which draws from the upper part. The waters of the Cascade springs are not analyzed. The chalybeate springs near Ann Arbor, although no analysis of the water is given, are in all probability wells in the drift (see analyses Nos. 55 and 66, from Winchell's biennial report, 1861, page 203, and Geology of Washtenaw County, 1881), and those of Wayne County may be from the drift, and are likely to be wells just above the rock. As Peale remarks, wells are often called springs, especially when the water rises markedly when struck. The Springville well is probably from the drift, but the water is not analyzed. The Eaton Rapids springs and well are flowing wells from the Coal Measures and the Parma. (Analyses Nos. 243 to 247.) The proportions of $CaCO_3$ and potash in these analyses are characteristically large.

The Erie sulphur springs are only examples of a great number of sulphur springs in the same region, flowing wells to or into the Dundee (upper Helderberg or Corniferous) limestone, of the same class as the Wyandotte or Riverside wells (analyses Nos. 296 and 300). Flint's magnetic springs at Three Rivers, in St. Joseph County, being saline are probably in the rock, as the drift well waters in that part of the State are not usually saline; while on the other hand the Berea or other saline beds of the Coldwater shales may readily be struck. The Fruitport artesian and magnetic well shows by its record and its temperature (48° F.) that it draws water from the Marshall. The water of the Grand Haven mineral spring is similar in analysis, and also comes from the Marshall (see analyses Nos. 264 to 266). The Grand Ledge water is probably from the Coal Measures. The Hubbardston magnetic spring

[1] See also Winchell's biennial report, 1861, p. 182.

Constituent.	94. Kalamazoo No. 2.	95. Dimondale.	96. Adrian.	97. Stanton.	98. Rochester.	99. Battle Creek.	100. Owosso.
$CaCO_3$	9.80 .140	12.95 .185	8.75 .125	13.25 .189	14.50 .207	.....	10.78 .154
$CaSO_4$	1.60 .023	.27 .004	Tr.	1.54 .022	2.00 .029	.....	2.10 .03
Fe_2O_3	.30 a .004	.05 .001	.....	.....	1.00 .014	.....	.....
$MgCO_3$	4.66 .067	5.25 .075	6.62 .095	5.81 .083	2.25 .032	.....	9.52 .136
KCl	.....	.28 .004	.....	.....	.....	.....	.....
SiO_2	.....	.20 .003	.....	1.00 .014	.....	.....	.07 .001
NaCl	1.64 .023	.70 .01	.35 .005	.40 .006	.75 .011	2.00 .029	2.10 .03
Volatile at red heat	3.00 .043	2.70 .039	7.00 .100	2.00 .029	3.00 .043	16.00 .229	1.68 .024
Total	21.00 .30	22.40 .32	22.70 .324	23.00 .329	24.50 .35	25.00 .357	26.25 .375
Total hardness	14.°	.....	15.5°	21.°	19.°	10.°	.....
Permanent hardness	6.°	.....	10.°	10.°	8.°	9.°	.....
Nitrates	.0005	.....	.....	.....	Tr.	.....	.....
Free ammonia	.00005	.00002	.00015	.....	.00005	.00003	.....
Albuminoid ammonia	.00002	.00001	.00020	0.0	.00001	.00025	.....
O from permanganate	.00025	.....	.....	.....	.....	.....	.....

Constituent.	101. Port Huron.	102. Howell.	103. Tecumseh.	104. Moline.	105. Belding.	106. Lapeer (Home of Feeble-Minded).	107. Lapeer.
$CaCO_3$	8.40 .12	14.10 .201	14.28 .204	11.20 .160	39. .557	.....	.....
$CaSO_4$	5.35 .077	2.00 .029	4.50 .064	1.35 .019	2.80 .04	9.90 .141	.....
Fe_2O_3	Tr.	1.00 .014	.10 .001	.50 .007	.20 .003	.08 .001	.....
$MgCO_3$	3.15 .045	5.00 .071	6.62 .095	12.25 .175	.50 .007	3.42 .049	.....
SiO_2	.....	1.40 .20	.....	1.00 .014	.....	.30 .004	.....
NaCl	.53 .008	1.00 .014	.50 .007	.80 .011	5.00 .071	5.40 .077	b 16.33 b .233
Na_2SO_4	.....	.....	.....	.....	.....	20.10 .287	.....
Volatile at red heat	10.5 .15	3.60 .051	6.00 .086	5.8 .083	3.70 .05	4.20 .60	20. .286
Total	28.00 .40	28.10 .401	32.00 .457	32.9 .470	51. .729	43.40 .620	80. 1.143
Total hardness	17.°	20.°	17.°	.....	.....	11.°	14.°
Permanent hardness	9.°	10.°	6.°	.....	.....	7.°	10.°
Nitrates	.....	.000	.....	.....	.....	Tr.	.002
Nitrites	.....	.....	.....	.....	.....	Tr.	0
Free ammonia	.00005	.00006	.....	.....	.000003	.00001	.00001
Albuminoid ammonia	.00009	.00005	.....	.....	.000001	.00003	.000004
Oxygen of permanganate reduced.	.....	.....	.....	.....	.0005	.....	.....

a + SiO_2.

b All chlorides.

onstituent.	108. Saginaw (Brand & Hardin).	109. Saginaw (Washington ave.).	110. Saginaw (Tower Block).	111. St. Charles.	112. Bay City.	113. St. Louis.	114. Saginaw (William Hicks).
₃	3.00 .043	6.40 .091	11.55 .165	8.40 .120	14.70 .210	.....	.....
e	5.40 .077	9.20 .131	.....	9.80 .140	31.99 .457	39.90 .570	28. .400
.....	.....	.....	23.10 .330	.....	.....	.....	.....
;	.35 .005	.50 .007	.....	.....	.....	.35 .005	Tr.
O_3	3.92 .056	5.50 .079	.....	8.50 .121	8.47 .121	26.81 .383	.....
O_4	.....	.....	.....	.....	.....	.....	15.3 .219
.....	.....	.....	.....	.....	.....	13.65 .195	.....
.....	1.00 .014	1.00 .014	.....	.....	a .14 .002	.28 .004	.5 .007
.....	28.83 .412	30.28 .433	2.00 .029	32.90 .470	53.20 .760	100.31 1.433	118.7 1.696
O_4	19.00 .271	20.12 .287	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	2.1 .003
l mineral	.....	.....	.....	.....	.....	200.20 2.861	.....
tile at red heat	5.50 .079	6.00 .086	3.00 .043	8.40 .120	10.50 .150	.....	17.5 .25
Total	67.0 .957	79. 1.129	50.10 .716	68.00 .971	119. 1.700	.....	210. 3.000
l hardness	14.°	18.°	.....	.....	18.°	.....	19.°
anent hardness	10.°	13.°	.....	.....	14.°	.....	18.°
tes	.....	.021	.....	.....	.....	.....	.....
tes	.....	0.0	.....	.....	.....	.....	.....
ammonia	.....	.00050	.....	.....	.00013	.00003	.....
minoid ammonia	.....	.00025	.....	.....	.00003	.00002	.....

Constituent.	115. Flushing No. 1.	116. Flushing No. 2.	117. Flushing No. 3.	118. Flushing No. 4.	119. Frost.	120. Vassar.	121. Caro.
O_3	9.00 .129	.....	.....	2.80 .04	20.60 .294	.....	21.00 .30
O_4	.....	.....	.....	.....	20.00 .286	105.7 1.51	185.50 2.65
s	2.00 .029	.....	.....	.....	.25 .003	1.0 .014	.70 .01
O_3	1.13 .016	1.00 .014	2.00 .029	1.00 .14	13.30 .19	17.5 .25	19.60 .28
.....	.....	.....	.....	.....	.....	.....	3.50 .05
O_4	.....	.....	.....	.....	.....	10.5 .15	.....

a + Fe_2O_3.

Constituent.	115. Flushing No. 1.	116. Flushing No. 2.	117. Flushing No. 3.	118. Flushing No. 4.	119. Frost.	120. Vassar.	121. Caro.
SiO_2	*5.00* .071				*1.15* .016	*1.5* .021	
NaCl	*158.69* 2.267	*141.27* 2.018	Not determined.	*122.* 1.743	*168.70* 2.41	*277.2* 3.96	*466.90* 6.67
Na_2CO_3	*17.08* .244	*22.00* .314	*42.50* .671	*41.00* .586			
Na_2SO_4	*89.00* 1.271	*3.30* .05	*7.80* .111	*5.40* .077			
Total mineral	*289.90* 4.156						
Volatile at red heat		*4.90* .07	*9.80* .140	*7.00* .10	*14.* .2		
Total		*181.10* 2.573	*233.80* 3.340	*179.30* 2.56	*238.* 3.400	*415.4* 5.906	*697.20* 9.96
Total hardness		2.°	4.°				
Permanent hardness		1.°	1.5°				
Free ammonia		.00012	.00015		.00015		
Albuminoid ammonia		.00002	.00002		.00005		

Constituent.	122. Wales.	Constituent.	122. Wales.
$CaCl_2$	*59.64* .852	KCl	*5.00* .071
$CaSO_4$	*1.00* .014	NaCl	*1152.88* 16.47
Fe_2O_3	*.74* .011	Total mineral residue	*1255.8* 17.94
MgCl	*36.54* .522		

Of the foregoing analyses No. 110, and doubtless others, should be credited to Prof. R. C. Kedzie alone. It should not be forgotten that these are not all the analyses furnished me by the Professors Kedzie, but only those which I preferred not to class geologically.

The first analysis of this list, being doubtless of water from the Grand Haven waterworks, which obtain their supply from driven wells, might perhaps have been included among those in the Pleistocene if the very low percentage of mineral matter did not suggest that the source is practically Lake Michigan, filtered through sand. The analysis is suggestively similar to that of Muskegon Lake (No. 2).

There is next a series of analyses, Nos. 82 to 105, in every respect comparable to the series Nos. 55 to 89. As arranged, the solids increase from one-fifth to one-half of an ounce per cubic foot of water, which is the normal range. The carbonates invariably form by far the largest proportion of the solid matter. The amount of gypsum is usually barely a tenth as great, and there is a small but variable amount of salt, which does not increase regularly with the amount of mineral matter, and when high may be assigned in part to sewage con-

nination. The wells furnishing these waters occur all over the State ɔept in the central region around Midland. It is noteworthy that ɔ percentage of solids is most commonly near 0.30 per thousand, and ɔ hardness correspondingly near 15°. There is no reason why any of ɔse analyses may not be of waters from common wells in surficial posits, and most of them are undoubtedly such. No. 83, from Reed ty, is of water from a region where I could find no wells which had ached bed rock, even when 100 feet deep. The same statement holds ıe at Ludington. On the other hand, in cases like Owosso the well ıy pierce bed rock a little, though near Owosso plenty of water and en flows are found in the drift. Taken as a whole, the analyses long to a fairly well-defined type of water from the drift.

With only two transitional analyses, those at Lapeer (Nos. 106 and 7), we pass, with an increasing proportion of solid matter, to an tirely different type of analysis. The total solids quickly double in nount, reaching about an ounce per cubic foot. But the lime and mag-ɜsia, or at any rate the carbonates, fall off, and instead there are sul-ıates and salt. Frequently there is more chlorine and sulphuric acid an can be satisfied by their usual bases, sodium and calcium, and we ıve sodic sulphate, potassic chloride, and other salts.

All the places from which analyses of this type come are well within e basin of the Marshall sandstone, except Wales and Vassar, and ay be supposed to derive their percentage of sulphates from the gyp-m of the Michigan series and the decomposing sulphide of iron that curs with the coal.

Some of these analyses—e. g., those from Saginaw (Nos. 108 to 110), ɪm St. Charles (No. 111), from Bay City (No. 112), and from St. Louis o. 113, compare No. 78)—show a considerable amount of lime and no ɪre mineral matter than often occurs in waters from drift wells of this ɡion, and may either be from such wells or from wells that go a short ıtance into the rock. On the other hand, wells like the Flushing lls, with water containing so low a percentage of lime, yield waters extremely soft that one can hardly believe them to be derived from ɔ drift, when he considers how much limestone and gypsum are dis-ninated through them. From the evidence of the analyses alone, ɜrefore, one could say that the water must come from some of the al-Measure sandstones below the drift, like the water of the Ban-ɔft House, Saginaw (the prominent hotels in Saginaw have their own ɜesian wells down into the sandstone), tests of which indicate water this character with Na_2SO_4. The Saginaw analyses are interme-ıte in character, as would be natural in waters from wells just from e base of the drift, but the generally sulphated type is confirmed by e analyses of Heim Brothers. The water of analysis No. 108 is ported by Kedzie as "colorless, odorless, nearly tasteless, and good r domestic use." The water of No. 109 is only "fair, having too much lphates." Both blacken very slightly on ignition. The water of No.

110 is "clear, bright, tasteless, and odorless; would be excellent but for the large amount of sulphates." The Brand & Hardin well (analysis No. 108) gave Heim Brothers 0.879 solids (61.5 grains per gallon), and the Washington avenue well (analysis No. 109) 1.043 solids (73 grains per gallon). Our inference that the waters of the Flushing analyses come from wells in the Coal Measures is confirmed by the fact that there are many such rock-drilled wells there. The well of W. Wartzel (analysis No. 119) was said to have been bored in 1896 to a depth of only 40 feet. The water flows naturally, with several feet head; temperature about 45°; specific weight in 1899, 1.007. Analyzed March 5, 1899. The last three analyses show more mineral matter than the water from any drift well known. The Vassar and Caro wells would naturally tap the gypsiferous Michigan series, and the Wales well the Berea grit. In confirmation of this supposition the Vassar and Caro analyses are strong in sulphates, while the Wales analysis is strong in salt and the earthy chlorides and low in sulphates—a thoroughly characteristic Berea grit analysis. Accordingly, analyses Nos. 82 to 104 are most probably of water from wells in the drift; analyses Nos. 108 to 121 of water from the Carboniferous above the Marshall, while No. 122, from Wales, is of water from the Berea, and may be compared with analyses at Birmingham (No. 285) and Utica (No. 225), towns which are similarly situated.

SANITARY ANALYSES BY PROF. V. C. VAUGHAN.

In the large and interesting list of sanitary analyses which have been furnished by Prof. V. C. Vaughan some are not complete, and frequently the total solids are not given. It seemed impracticable, therefore, to arrange them in the usual way, and hence they have been given a special tabulation of their own. The gaps in his numbering (given in parentheses) are in general due to the omission of analyses from other States or from the northern peninsula of Michigan.

There is a general parallelism between this series of analyses and those of Professor Kedzie, and many cross references have been inserted. It will be found that many of the analyses showing especially small amounts of solids belong in one of three classes. (1) Like the Petoskey (analyses Nos. 130 to 132), they are probably surface waters, or from lakes; or (2) there is good independent evidence that they are strictly surficial, largely from rain-water wells; or (3) they come from the sands of the modified drift or glacial drainage, like that at Lowell (analyses Nos. 123 and 124). It is noteworthy that inoculation is nearly as likely to produce bad results in these as in more highly mineralized waters. In other words, exceptionally low mineralization often means dilution with rain water, and that implies exposure to surface contamination. As in the Kedzie analyses, the vast bulk of these samples contain from one-fifth to one-half of an ounce of solid matter per cubic foot. The analyses are rather widely distributed, though of course the more populated

s of the Lower Peninsula has the greater number. Most of these lyses are doubtless of water from wells in the drift (i. e., Pleistocene), ough some, e. g., Eastlake and Manistee (analyses Nos. 146 and), may be of water from the lakes, and others, like some of the sing analyses, may be of waters from rock wells and belong to the owing section.

here is a somewhat larger number of transition analyses than in case of the Kedzie analyses, having from 0.500 to 0.650 parts per sand (ounces per cubic foot) of solids. Some of these evidently ng to the previous group, however, and merely have more organic ter than usual. (See analyses Nos. 205 to 211.) Other analyses of waters from wells which in all probability draw their supplies bed rock, e. g., the Saginaw well (analysis No. 214), with its comatively soft water, is probably of the sodic-sulphate type. It is th noting that all such wells, except No. 209 at Kalamazoo, are hin the area covered by rocks above the Marshall, and should probabe included among the analyses of the next section. The remaining lyses, with the exception of one or two (No. 217—water presumably taminated with the waste bittern of salt manufacture—and No. 218), most probably of waters from rock, and usually there is corroboraevidence which renders it possible to fix also the stratum from ch the water comes.

The Holt well (analysis No. 221) probably draws water from the and Rapids limestone or from a horizon near.

The Holland (analysis No. 219), low in sulphates and strong in chloes, is an analysis characteristic of water from the Marshall. A ilar analysis of water within the coal basin would suggest strong ntamination. The Wyandotte water (analysis No. 220) would seem be from the Dundee limestones. The Adrian waters (analyses No. 2, etc.) are peculiar. It may be that they are contaminated with sulate of iron from the sulphides in the Ohio black shale.

The two Imlay City wells (analyses Nos. 223 and 224) almost certainly aw water from the Coldwater shales or the lower Marshall. Under lay City water from the Berea would be much salter, as the Wales d other analyses show, and that from the Napoleon sandstone would ntain less salt.

The Utica well (analysis No. 225) is shown to be in the Berea, by the me line of argument which applies to the Wales well (analysis No. 2), which is similarly situated and connects the Utica well with the rmingham wells. The latter are certainly in the Berea.

No. 299, water from Alpena, is classed solely on the basis of its alysis, which resembles the tests of waters from the rock wells of lpena in the Traverse or deeper limestones.

The analyses of waters from around Bay City are very puzzling, ring to the leakage from deep salt wells, and Prescott's paper tends warn against rashness in diagnoses.

In the analyses reported by Vaughan the number, according to Vaughan's list, follows in parentheses after the serial number (the numbers omitted representing analyses outside our purview). Next follows the identification—the name of the place, the date of the analysis, and, when stated, the origin of the water. The water is understood to be colorless, odorless, and neutral, if nothing to the contrary is stated. The hardness is given on the usual (Clark's) scale—i. e., the number of grains of $CaCO_3$ per gallon which would be required to make a water equally hard. The total residue (obtained by evaporation at 110° C.) and total inorganic residue are self-explanatory. As remarked, the specific gravity of the water is neglected, which makes a perceptible error only in the analyses from No. 217 on. The quantities are in parts per thousand. The row of figures after "organic" (i. e., loss on ignition) obviously represents the differences between the two residues. The chlorine is computed as salt (NaCl). The next row of figures above gives the parts of potassium permanganate reduced by organic matter, and, in the rows above, the free and albuminoid ammonia, and the nitrates (N_2O_5) and nitrites (N_2O_3) in parts per thousand. The sulphates when given are computed as SO_3. It will be noticed that the ammonia is quite prominent even in the waters from such wells as the Mount Pleasant of the previous section, which is deep and free from possible surface contamination (analyses Nos. 79 and 80). The first two rows of figures give the biological examination, viz, the result of inoculation of cultures on the health of animals (no effect on the health being indicated by a —) and the number of bacteria per cubic centimeter after standing 72 hours.

Professor Vaughan gives the following explanatory notes:

While no absolute standard for the chemical purity of drinking water can be given, the following conclusions may be regarded as approximately correct:

(1) The total residue should not exceed 500 parts per million.

(2) The inorganic residue may constitute the total residue.

(3) The smaller the amount of organic residue the better the water.

(4) The amount of earthy bases should not exceed 200 parts per million.

(5) The amount of sodium chloride should not exceed 10 parts per million. A larger amount may be expected, however, in certain salt-producing districts.

(6) The amount of sulphates should not exceed 100 parts per million.

(7) The organic matter in 1,000,000 parts of the water should not reduce more than 8 parts of potassium permanganate.

(8) The amount of free ammonia should not exceed 0.05 parts per million.

(9) The amount of albuminoid ammonia should not exceed 0.15 parts per million.

(10) The amount of nitric acid should not exceed 0.5 parts per million.

(11) The best waters contain no nitrous acid, and any water which contains it in quantity sufficient to be estimated should not be regarded as a safe drinking water.

The word trace ("tr.") whenever used indicates the existence of the substance in quantity sufficient to be recognized by the test, but too small to be determined quantitatively.

Explanation of microscopical examination, i. e., description of deposit, if any, magnified 100 diameters and 500 diameters:

Six ounces of water are placed in a conical glass, and the deposit, if any, is examined after from 12 to 24 hours. The presence of any appreciable deposit, especially

if it be of animal or vegetable nature, would detract from the suitability of the water.

The bacteriological examination consists in counting the number of germs developed on a gelatine plate inoculated with one drop of water:

(1) After 24 hours, (2) after 48 hours, (3) after 72 hours. Then follow remarks on the kinds of germs observed.

Inoculation experiments are conducted as follows:

The animals inoculated with germs are white rats, guinea pigs, or rabbits; the method of inoculation, into abdominal cavity. The kind, amount, and age of culture used is noted, the effect on the animal's health, and eventually its post-mortem appearance. One drop of the water is added to 1 dram of some culture medium, such as beef tea, and this, after it has been kept at the temperature of the body for 24 hours or longer, is used for inoculating the animals.

	123 (190). Lowell, T. 6 N., R. 9 W.	124 (192). Lowell, T. 6 N., R. 9 W.	125 (169). Pontiac.	126 (168). Sand Beach.	127 (369). Lansing.	128 (257). Port Huron.	129 (320). Pontiac.
Result of inoculation	—	+	—	—	—	—	+
Number of bacteria in 72 hours	25	Liquefied.	4874	812	230	Liquefaction.	400
Nitrites	.....	Tr.	.....	.....	.....	.....	Tr.
Nitrates	.....	Tr.	.....	.....	.....	Tr.	Tr.
Albuminoid ammonia	0.0004	0.0005	0.00006	0.00008	0.000021	0.000126	0.000174
Free ammonia	Tr.	Tr.	.00002	.00002	.000012	.000006	.000044
K Permanganate reduced	.0015	.002	.002	.002	.002	.....	.....
Chlorine as NaCl	.0008	.0005	.002	.002	.00625	.00625	.00148
Organic residue	.005	.007	.011	.020	.017	.030	.012
Inorganic residue	.023	.023	.024	.035	.041	.040	.0564
Total residue	.028	.030	.035	.055	.058	.070	.0704
Hardness	8.°	3.°	2.5°	5.5°	4.°	2.°	6.°
Sulphates	.....	.....	.....	Tr.	.....	Ft. tr.	.....

No. 123 (190). Lowell, T. 6 N., R. 9 W. July 17, 1893. Microscope shows molds. The hardness assigned to this and the following analysis is not consistent with the low amount of total solids.

No. 124 (192). Lowell, T. 6 N., R. 9 W. July 7, 1893. Microscope shows a few vegetable fibers.

No. 125 (169). Pontiac. December 16, 1892. Microscope shows indeterminate granules. This is so much softer than any of the other Pontiac analyses (Nos. 129, 133, 139, 150, 175, 190–192, 211, and 218) that, as is in the previous analysis, rain-water contamination is indicated.

No. 126 (168). Sand Beach. December 6, 1892. From a well which must be shallow, as deeper wells seem pass into the Coldwater series and are saline. Microscope shows indeterminate granules.

No. 127 (369). Lansing. September 6, 1897. From the waterworks, which draw their supply chiefly from wells in gravel beneath clay; but deep rock wells have also been bored. Very small amount of organic matter.

No. 128 (257). Port Huron. March 9, 1895. Microscope shows wood fiber, algæ, unicellular plants and animals, vegetable débris, inorganic deposits. Color, milky; odor, musty; reaction, alkaline.

No. 129 (320). Pontiac. July 10, 1896. From a well which is almost certainly a shallow one in the drift. Microscope shows a small amount of vegetable and inorganic débris.

	130 (205). Petoskey.	131 (206). Petoskey.	132 (207). Petoskey.	133 (95). Pontiac.	134 (245). Grand Rapids.	135 (157). Bay City.	136 (136). Ithaca.
Result of inoculation.	—	—	—	—	—	.....	—
Number of bacteria in 72 hours	0	0	0	190	2,600	570	0
Nitrites	.....	.....	Tr.	.....	.....	Tr.	.....
Nitrates	.....	.....	.....	Very slight tr.	Strong tr.	Tr.	.....
Albuminoid ammonia	0.000008	0.000006	0.000006	0.000574	0.000113	0.000125	0.00024
Free ammonia	.000002	.000002	.000002	.000422	.000014	.000344	.000302
Permanganate reduced	.....	.....	.....	.02212	.....	.0158	.05114
Chlorine as NaCl	.00082	.00082	.00082	.0099	.0165	.0145	.028
Organic residue	.040	.050	.040	.054	.040	.015	.060
Inorganic residue	.050	.050	.070	.070	.100	.133	.089
Total residue	.090	.100	.110	.124	.140	.148	149
Hardness	7.°	7.°	7.°	12.°	4.5°	11.3°	10.2°
Sulphates	.....	.....	.....	.....	Tr.	Strong tr.	Tr.

No. 130 (205). Petoskey. February 9, 1894. Microscope showed small amount of algæ and plant detritus, reaction alkaline.

No. 131 (206). Petoskey. February 9, 1894. Microscope showed small deposit of unicellular plants and plant detritus, reaction alkaline.

No. 132 (207). Petoskey. February 9, 1894. Microscope showed inorganic matter, algæ, and plant detritus, reaction alkaline.

No. 133 (95). Pontiac. August 21, 1890. Town water supply; slightly turbid. Microscope (100 diameters) showed organic material, yellow, red, and black, animalculæ; (500 diameters) several species of diatoms, green algæ, blue algæ, amœbæ, violet spores, yellow reticulated organic material, fibers, Entomostraceæ.

No. 134 (245). Grand Rapids. December 20, 1894. Slightly milky, alkaline. Microscope showed inorganic matter, vegetable débris, a few unicellular plants.

No. 135 (157). Bay City. October 1, 1892. Microscope showed carbonate of lime, pigment granules, bits of woody fiber, flocculent matter. It is a well, and judging by analysis is shallow.

No. 136 (136). Ithaca. February 12, 1892. Microscope showed crystals of calcium carbonate; cloudy.

	137 (305). East Tawas.	138 (79). East-lake.	139 (97). Pontiac water supply.	140 (133). Hastings.	141 (178). North-ville.	142 (239). Petoskey.	143 (132). Ithaca.
Result of inoculation.	—	—	—	—	+	—	+
Number of bacteria in 72 hours	27	.....	18	850	4,300	400	500
Nitrites	Tr.	.....	Very slight tr.	Tr.	Tr.	Tr.	.....
Nitrates	Tr.	0.000202	Very slight tr.	Tr.	Tr.	.....	.....
Albuminoid ammonia	0.000062	.000058	0.00035	0.00011	0.00005	0.00012	0.00016
Free ammonia	.0000053	.000067	.00013	.0002	.00001	.00002	.00041
Permanganate reduced	.....	.0004662	.02307	.1311	.0075	.....	.04318
Chlorine as NaCl	.0099	.04474	.0099	.018	.0035	.00165	.025
Organic residue	.090	.0630	.064	.065	.047	.040	.072
Inorganic residue	.060	.101	.101	.105	.140	.150	.118
Total residue	.150	.164	.165	.170	.187	.190	.190
Hardness	7.9°	4.70°	11.5°	11.6°	15.°	9.°	9.5°
Sulphates	.....	.0485	.....	Tr.	Tr.	.....	Tr.

No. 137 (365). East Tawas. March 7, 1896. Alkaline. Microscope shows inorganic matter and vegetable débris.

No. 138 (79). Eastlake. May 13, 1890. From a well. Microscope (100 diameters) shows slight aces of fresh-water algæ; (500 diameters) a few threadlike Vibrios.

No. 139 (97). Pontiac. August 21, 1890. Town water supply. Microscope (100 diameters) shows llow organic material, fibers; (500 diameters) many short, rod-shaped germs, several species of atoms, fibers, Palmellaceæ, Entomostraceæ.

No. 140 (133). Hastings. February 3, 1892. From a well and smells musty. Microscope shows vegetable fibers, molds, Paramecia.

No. 141 (178). Northville. September 30, 1893. From a well. Microscope shows some vegetable thris.

No. 142 (239). Petoskey. September 20, 1894. Alkaline. Microscope shows algæ, infusoria, bacteria, lant detritus, inorganic matter.

No. 143 (132). Ithaca. February 3, 1892. Microscope shows dust and dirt, cloudy in color, with a light odor.

	144 (363). Battle Creek.	145 (246). Grand Rapids.	146 (364). Eastlake.	147 (138). Holland.	148 (341). Traverse City.	149 (256). Port Huron.	150 (96). Pontiac.
Result of inoculation.	—	—	—	—	—	+	—
Number of bacteria in 72 hours	14,020	1,300	263	340	Liquefied.	Liquefaction.	48
Nitrites	Tr.	.....	Tr.	Tr.	.....	.....	.0109
Nitrates	.....	Tr.	0.00005	Tr.	Tr.	Tr.	Very slight tr.
Albuminoid ammonia	0.0000298	0.000126	.00014	0.000166	0.0000846	0.000122	0.000802
Free ammonia	.000005	.000009	.000065	.000514	.0000026	.000007	.000288
Permanganate reduced	.002	.....	.002	.02212	.002	.....	.012644
Chlorine as NaCl	.0122	.0099	.002	.015675	.00625	.0099	.009675
Organic residue	.062	.09	.091	.090	.096	.07	.124
Inorganic residue	.137	.110	.111	.120	.123	.150	.096
Total residue	.199	.20	.202	.210	.219	.220	.220
Hardness	7.6°	8.°	11.°	9.°	13.2°	2.1°	11.5°
Sulphates	.....	0	.....	Tr.	.....	Tr.	.....

No. 144 (363). Battle Creek. August 10, 1897. Microscope shows small amount of organic débris.

No. 145 (246). Grand Rapids. December 20, 1894. Colorless and odorless; alkaline. Microscope shows small deposit of no significance. This is one of a long series. (See index.)

No. 146 (364). Eastlake. August 11, 1897. Microscope shows a small amount of amorphous matter.

No. 147 (138). Holland. March 2, 1892. From a deep well. Cloudy. Microscope (100 diameters) shows indeterminate granules; (500 diameters) vegetable detritus. This is probably from the Marshall sandstone, as rock is not far from surface at Holland, but the expression "deep" may mean only beneath the clay.

No. 148 (341). Traverse City. November 4, 1896, at the same time as No. 163. Microscope shows very small amount of vegetable débris. (See index for other analyses.)

No. 149 (256). Port Huron. March 29, 1895. Milky, musty, alkaline. Microscope shows algæ, wood fiber, inorganic deposits, much vegetable débris, unicellular plants and animals.

No. 150 (96). Pontiac. August 2, 1890. Town water supply. Microscope (100 diameters) shows yellow organic material, colorless fibers; (500 diameters) many short, rod-shaped germs, several species of diatoms, yellow algæ, orange algæ, Cymbella ehrenbergii, fibers, Entomostraceæ.

	151 (167). Eastlake.	152 (279). Caro.	153 (270). Manistee.	154 (241). Grand Rapids.	155 (176). Kalamazoo.	156 (237). Grand Rapids.	157 (235). Grand Rapids.
Result of inoculation	+	—	—	—	—	—	+
Number of bacteria in 72 hours	180	25	Liquefaction.	2,500	350	160	200
Nitrites	Tr.	Tr.	.....	Tr.	0.0003	Tr.	Tr.
Nitrates	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.
Albuminoid ammonia	0.00071	0.00002	0.000075	0.00004	.00012	0.00008	0.000036
Free ammonia	.0003	.00019	.000003	Tr.	.00004	.000006	.000008
Permanganate reduced	.10902	.005	.....	.....	.0012	.....	.....
Chlorine as NaCl	.01419	.006	.00165	.0165	.00247	.00713	.00713
Organic residue	.110	.029	.050	.090	.090	.070	.080
Inorganic residue	.114	.201	.180	.140	.160	.180	.170
Total residue	.224	.230	.230	.230	.250	.250	.250
Hardness	16.5°	5.6°	8.5°	9.°	10.°	8.°	8.°
Sulphates	.....	Tr.	Tr.	Tr.	Tr.	.....	.....

No. 151 (167). Eastlake. November 21, 1892. From town supply pipes. Clear after filtering; putrid odor on standing. Microscope shows vegetable débris. (Compare with No. 138; the deep-rock well character of this water is plain.)

No. 152 (279) Caro. July 27, 1895. Microscope shown vegetable débris. Cloudy, alkaline.

No. 153 (270). Manistee. June 29, 1895. Probably from lake. Slight milkiness, alkaline. Microscope shows vegetable débris and inorganic matter, algæ, infusoria. Agrees quite closely with Nos. and 146.

No. 154 (241). Grand Rapids. November 5, 1894. Alkaline. Microscope shows algæ, desmids diatoms, bacteria, infusoria, vegetable débris, inorganic matter.

No. 155 (176). Kalamazoo. October 31, 1893. Odor stale; alkaline. Microscope shows vegetable débris, with vegetable and animal microorganisms.

No. 156 (237). Grand Rapids. September 4, 1894. Alkaline. Microscope shows algæ, infusoria inorganic matter, vegetable débris.

No. 157 (235). Grand Rapids. September 4, 1894. Alkaline. Microscope shows inorganic matter vegetable débris, infusoria, algæ.

	158 (227). Grand Rapids.	159 (139). Holland.	160 (224). Grand Rapids.	161 (271). Manistee.	162 (225). Grand Rapids.	163 (342). Traverse City.	164 (365). Traverse City.
Result of inoculation	+	—	+	—	+	+	—
Number of bacteria in 72 hours	Liquefaction.	120	Liquefaction.	Liquefaction.	Liquefaction.	Liquefied.	12
Nitrites	.....	Tr.	.....	.....	.....	.....	.....
Nitrates	Tr.	Tr.	.....	Tr.	.....	Tr.	.....
Albuminoid ammonia	0.00003	0.0000134	0.0002	0.000082	0.000215	0.0000346	0.00006
Free ammonia	.000016	.000088	.00098	.000006	.000055	.0000026	[illegible]
Permanganate reduced	.....	.00948	.....	.....	.....	.002	.002
Chlorine as NaCl	.0165	.00693	.01485	.00247	.01485	.00825	[illegible]
Organic residue	.090	.070	.057	.07	.167	.120	[illegible]
Inorganic residue	.160	.180	.202	.190	.113	.160	.185
Total residue	.250	.250	.259	.260	.280	.280	.285
Hardness	11.°	10.°	12.°	9.1°	12.°	13.2	11.
Sulphates	.....	Tr	.....	Tr.	.....	.....	Slight tr.

No. 181 (273). Ann Arbor. July 15, 1895. Probably from wells. Microscope shows inorganic deposit. (See index for other analyses.)

No. 182 (370). Lansing. September 30, 1897. City water supply. Probably principally from wells to the base of the drift. Kedzie gives .271 total solids, of which .157 is organic, .0008 free, and .0001 albuminoid ammonia, with a hardness of 13°. There is probably an error in the hardness given. Opalescent. Microscope shows small amount of organic matter.

No. 183 (175). Ann Arbor. December 1, 1893. From well. Slight milkiness, alkaline. Microscope shows vegetable débris, inorganic matter. (Compare No. 38.)

No. 184 (105). St. Johns. January 17, 1897. Microscope shows crystals of NaCl, bacilli, Draparnalia, Conferva, Paramecia, diatoms.

No. 185 (197). Merrill. June 22, 1893. Microscope shows a few vegetable fibers. The low degree of hardness of the water from this well for the degree of mineralization is noteworthy and points to the presence of sodic sulphate.

	186 (293). Dowagiac.	187 (247). Grand Rapids.	188 (236). Grand Rapids.	189 (106). St. Johns.	190 (129). Pontiac.	191 (272). Pontiac.	192 (359). Pontiac.
Result of inoculation	—	—	—	—	—	+	—
Number of bacteria in 72 hours	45	700	150	3,464	30	Liquefaction.	63
Nitrites	.....	.....	Tr.	Very f. tr.	Tr.	.....	.....
Nitrates	.....	Tr.	Tr.	.....	Tr.	.....	.....
Albuminoid ammonia	0.00001	0.0001	0.000052	0.000122	0.0001	0.000036	0.000018
Free ammonia	.000021	.000012	.00001	.000094	.00018	.000024	.000028
Permanganate reduced	.....	.....	.00001	.11534	.003	.....	.004
Chlorine as NaCl	.00181	.0185	.00713	.01815	.012	.03775	.05675
Organic residue	.130	.070	.080	.132	.120	.050	.140
Inorganic residue	.220	.290	.280	.242	.250	.330	.240
Total residue	.350	.350	.360	.374	.380	.380	.380
Hardness	13.°	11.°	8.°	20.1°	15.5°	9.5°	6.7°
Sulphates	Tr.	.....	.....	.1455	.....	.....	.....

No. 186 (293). Dowagiac. November 19, 1895. Alkaline. Microscope shows deposit of inorganic matter. This differs from No. 168 mainly in organic matter.

No. 187 (247). Grand Rapids. December 20, 1894. Microscope shows inorganic matter, a few unicellular plants. Alkaline. (See index.)

No. 188. Grand Rapids. September 4, 1894. Microscope shows algæ, infusoria, vegetable fibers, and inorganic matter. Alkaline. (See index.)

No. 189 (106). St. Johns. November 7, 1891. Microscope shows crystals, colorless amorphous matter, diatoms, desmids, germs, navicula, NaCl crystals, fibers.

No. 190 (129). Pontiac. January 16, 1892. From a well, slightly turbid. Microscope shows freshwater algæ. This and the following analyses have a relatively large amount of organic matter.

No. 191 (272). Pontiac. July 1, 1895. Slightly milky, strongly alkaline. Microscope shows unicellular plants and animals, inorganic matter.

No. 192 (359). Pontiac. May 28, 1897. Microscope shows small amount of amorphous matter.

	193 (274). Sherwood.	194 (208). Petoskey.	195 (334). Union City.	196 (137). Holland.	197 (264). Adrian.	198 (371). Battle Creek.	199 (240). Ann Arbor.
Result of inoculation	+	—	+	—	—	—	—
Number of bacteria in 72 hours	Liquefied	0	Liquefied	20	Liquefaction.	85	.....
Nitrites	0.00004	.....	Tr.	Tr.	.....	Tr.	Tr.
Nitrates	Large amount.	.....	Tr.	Tr.	Ft. tr.	Tr.	.....
Albuminoid ammonia	0.00005	0.000012	0.000024	0.00009	0.000022	0.000014	0.00003
Free ammonia	.00006	.000006	.0000026	.000068	.00001066	.00001	Tr.
Permanganate reduced	.008	.....	.0035	.005672	.....	.002+	.....
Cl. as NaCl	.011	.00246	.01485	.01385	.012375	.330	.00098
Organic residue	.170	.140	.276	.217	.080	.056	.100
Inorganic residue	.210	.240	.112	.173	.320	.402	.320
Total residue	.380	.380	.388	.390	.400	.458	.420
Hardness	12.9°	11.°	13.°	10.5°	10.4°	5.9°	14.°
Sulphates	.....	.00540	Tr.	Tr.	.460	Tr.	Tr.

No. 193 (274). Sherwood. July 15, 1895. On June 20, 1893, a test (198) gave no inoculation effect and but 464 bacteria in 72 hours. This water has an undue amount of organic matter.

No. 194 (208). Petoskey. February 9, 1894. Slight yellowish brown color; reaction alkaline. Microscope shows small deposit of inorganic matter and plant detritus.

No. 195 (334). Union City. September 8, 1896. Opalescent. Microscope shows small amount of organic débris.

No. 196 (137). Holland waterworks, i. e., possibly from driven wells. March 2, 1892. Microscope (100 diameters) shows indeterminate granules; (500 diameters) vegetable fibers, molds.

No. 197 (264). Adrian. June 3, 1895. Yellowish, musty, alkaline. Microscope shows small inorganic deposit. Weakest of Adrian analyses.

No. 198 (371). Battle Creek, city pump. October 5, 1897. Microscope shows very small amount of organic matter.

No. 199 (240). Ann Arbor. November 3, 1894. Alkaline.

	200 (348). Union City.	201 (195). Howell.	202 (343). Manceiona, T. 29 N., R. 6 W.	203 (263). Adrian.	204 (288). Adrian.	205 (267). Grand Rapids.	206 (213). Saginaw.
Result of inoculation	—	—	—	+	+	—	—
Number of bacteria in 72 hours	Liquefaction.	Countless.	Liquefaction.	Liquefaction.	150	Liquefaction.	Liquefaction
Nitrites	Tr.	.....	Tr.	.....	Ft. tr.	.....	Tr.
Nitrates	Tr.	Tr.	Tr.	Ft. tr.	Tr.	Very distinct tr.	.....
Albuminoid ammonia	0.0000346	0.00016	0.0000453+	0.000036	0.00012	0.000058	.....
Free ammonia	.0000018	Very ft. Tr.	.0000093	.000016	.00008	.00001066	.....
Permanganate reduced	.004+	.....	.018—	.....	.....	.....	.....
Chlorine as NaCl	.0299	.000891	.00825	.01815	.0165	.0312	0.00196
Organic residue	.177	.200	.231	.150	.196	.180	.090
Inorganic residue	.253	.250	.231	.330	.284	.340	.500
Total residue	.430	.450	.462	.480	.480	.520	.530
Hardness	14.°	6.°	15.°	10.5°	12.°	7.8°	7.°
Sulphates	Tr.	.....	.....	.68978	Tr.	Ft. tr.	.....

No. 200 (348). Union City. January 22, 1897. From well. Microscope shows small amount of organic matter. (Compare Nos. 180 and 195.)

No. 201 (195). Howell. June 26, 1893. From proposed water supply. Microscope shows a few vegetable fibers, diatoms, etc. Agrees well with Kedzie's analysis.

No. 202 (343). Mancelona. November 14, 1896. From a well. Water similar to the lake water analysis No. 48). Inorganic, but with less organic matter. Light yellow, opalescent; odor marked. Microscope shows considerable amount of vegetable matter.

No. 203 (263). Adrian. June 3, 1895. Yellowish, musty, alkaline; diatoms, a few unicellular organisms, inorganic matter. There is some error in the amount of sulphates in these Adrian analyses Nos. 203, 204, 219); charged with decomposing sulphides.

No. 204 (288). Adrian. September 23, 1895. Dirty, yellow, stale, alkaline. Microscope shows large amount of inorganic matter, unicellular plants and animals.

No. 205 (267). Grand Rapids. June 19, 1895. Alkaline. Microscope shows small deposit of inorganic matter.

No. 206 (213). Saginaw. May 26, 1894. Alkaline. Microscope shows small deposit. (Compare No. 18; rather stronger than Saginaw River and yet much less mineralized than Nos. 108–110 and 214.)

	207 (166). Okemos.	208 (85). Gladwin.	209 (177). Kalamazoo.	210 (275). Sherwood.	211 (103). Pontiac (well).	212 (87). Gladwin.	213 (80). Gladwin.
Result of inoculation	—	+	—	+	—	—	—
Number of bacteria in 72 hours	Liquefied	Liquefied	200	Liquefied	265	12	315
Nitrites	0.00055	0.000271	.....	0.00003	.....	.....	Faint tr.
Nitrates	Heavy tr.	.....	Tr.	Large amount.	.....	.....	0.0000192
Albuminoid ammonia	0.00036	0.000102	0.000004	0.00004	0.000368	0.000116	0.000044
Free ammonia	.000158	.00026	.000002	.00003	.000366	.000526	.000874
Permanganate reduced	.1106	.0003614	.00316	.006	.04824	.04424	.0008
Chlorine as NaCl	.0049	.00132	.000625	.035	.04455	.02145	.0118
Organic residue	.270	.211	.030	.350	.280	.125	.153
Inorganic residue	.270	.334	.52	.220	.310	.473	.489
Total residue	.540	.545	.550	.570	.590	.598	.642
Hardness	14.5°	16.5°	11.°	12.°	7.5°	17.°	7.2°
Sulphates	.00582	.002425	.....	.....	.03497	.....	.0388

No. 207 (166). Okemos. November 18, 1892. From well. Microscope shows pigment granules vegetable débris, woody fiber.

No. 208 (85). Gladwin. June 10, 1890. From well with much organic matter. Microscope shows three varieties of crystals, yellow and green amorphous matter, a few germs. (See Nos. 212, 213.)

No. 209 (177). Kalamazoo. October 21, 1893. Alkaline. Microscope shows vegetable débris. (See index.)

No. 210 (275). Sherwood. July 15, 1895.

No. 211 (103). Pontiac. November 15, 1890. Microscope shows organic débris, brownish yellow amorphous matter, algæ; colorless, odorless amorphous matter and yellow amorphous matter; spherical germs, Oscillatoriæ, Draparnaldia, crystals of NaCl. The large amount of organic matter points to a surface water.

No. 212 (87). Gladwin. July 28, 1890. Microscope (100 diameters) shows vegetable fiber, yellow amorphous matter, crystals; (500 diameters) red amorphous material, yellow amorphous material, many bacilli, crystals, probably NaCl.

No. 213 (80). Gladwin. May 17, 1890. Turbid. Microscope (100 diameters) shows vegetable fiber and reddish amorphous matter; (500 diameters) 4 species of bacteria, a few diatoms, colorless crystals. (See No. 208.)

	214 (228). Saginaw.	215 (99). Parma.	216 (170). Bay City.	217 (102). Bay City.	218 (290). Pontiac.	219 (316). Holland.	220 (92). Wyandotte.
Result of inoculation	+	—	—	—	—	+	+
Number of bacteria in 72 hours	100	1,340	480	780	73	900	2,580
Nitrites	.....	0.000234	0.0023	.....	Tr.	Tr.	0.000247
Nitrates	Tr.	.01143	.005	0.000617	Tr.	Tr.	.01306
Albuminoid ammonia	.00026	.000124	.0000288	.00038	0.0002	0.00006	.00056
Free ammonia	.00004	.00224	.0008	.000176	.000016	.000007	.00046
Permanganate reduced	.....	.01896	.....	.05523	.037	.....	.04108
Chlorine as NaCl	.0099	.10065	.120	.33995	.014025	.08250	.2664
Organic residue	.040	.247	.340	.312	.42	.100	.240
Inorganic residue	.600	.452	.510	.578	.53	.970	.850
Total residue	.640	.699	.830	.890	.95	1.070	1.090
Hardness	2.°	10.5°	7.5°	16.°	6.°	13.°	13.°
Sulphates	Tr.	.3753	0	.01848	Tr.	Tr.	Strong tr.

No. 214 (228). Saginaw. August 11, 1894. From deep well. Note the relatively low hardness and compare with No. 116; probably a rock well. Alkaline. Microscope shows vegetable débris, algæ.

No. 215 (99). Parma. November 28, 1890. The amount of sulphates would be appropriate for a rock well. Microscope (100 diameters) shows fibers, yellow amorphous matter, white amorphous matter, algæ, animalculæ; (500 diameters) fibers, yellow amorphous matter, white amorphous matter, blue spores, short thick bacilli, paramecia, oscillatoriæ.

No. 216 (170). Bay City. March 7, 1893. Granular sediment, alkaline. Microscope shows fungus, spores, and monads.

No. 217 (102). Bay City. November 20, 1890. Microscope (100 diameters) shows fibers, yellow amorphous matter, colorless amorphous matter, germs; (500 diameters) algæ, diatoms, bacilli. Slightly cloudy, slightly musty. The organic matter and sulphates suggest contamination by salt wastes.

No. 218 (290). Pontiac. October 25, 1895. From well. Alkaline; slightly milky. Microscope shows vegetable débris.

No. 219 (316). Holland. May 15, 1896. Milky, alkaline. Microscope shows large amount of inorganic matter. (See index.) This well is probably in the Marshall sandstone, improperly cased.

No. 220 (92). Wyandotte. November 12, 1890. From well. Color, dirty. Microscope (100 diameters) shows crystals, yellow amorphous matter, white amorphous matter; (500 diameters) NaCl crystals, algæ. Yellow and white amorphous matter, precipitated sulphur.

No. 221 (209). Holt. February 9, 1894. Microscope shows deposit of inorganic matter, algæ, and plant detritus in small amount. (Compare Lansing analyses.) This is probably a rock well.

	221 (209). Holt.	222 (262). Adrian.	223 (88). Imlay City.	224 (86). Imlay City.	225 (357). Utica.
Result of inoculation	—	+	—	+	.....
Number of bacteria in 72 hours	2000	Liquefaction.	0	120	.....
Nitrites	Distinct tr.	.....	Ft. tr.	.....	.....
Nitrates	Distinct tr.	Ft. tr.	.....	.....	.....
Albuminoid ammonia	0.00005	0.00011	0.000102	0.000052	0.0000133
Free ammonia	.00003	.0002932	.000462	.00052	.000016
Potassium permanganate reduced	.008	.....	.0082	.000234	.006+
Chlorine as NaCl	.02475	.0528	1.32825	1.321	1.815
Organic residue	.430	.510	.240	.037	.280
Inorganic residue	.740	1.070	1.436	1.648	1.946
Total residue	1.170	1.580	1.676	1.685	2.226
Hardness	2.5°	8.8°	12.°	12.°	10.°
Sulphates	Tr.	1.01784	.....	.21828	.....

No. 221 (268). Adrian. June 3, 1895. Very yellow, foul, alkaline. Microscope shows small inorganic deposit. (See Nos. 203, 204.)

No. 222 (88). Imlay City. July 28, 1890. Microscope (100 diameters) shows red amorphous material, crystals; (500 diameters) cubic crystals, feathery algæ.

No. 224 (86). Imlay City. June 24, 1890. Microscope (100 diameters) shows considerable sediment, yellow amorphous matter; (500 diameters) colorless triangular prisms. A few red spots in the yellow organic matter. Note the large amount of salt in these two analyses; almost certainly from a rock well, perhaps 708 feet deep. (See Geol. Survey Mich., Vol. V, Pt. II, Pl. XXII.)

No. 225 (357). Utica. May 3, 1897. From well. Slightly opalescent. Microscope shows very small amorphous deposit. (Compare with Birmingham analyses.)

MISCELLANEOUS ANALYSES.

Constituent.	226. Owosso.	227. Owosso.	228. Leslie.	229. Chesterfield.	230. Sanford.	231. Hudson.
Al_2O_3	Tr.	(a)				0.00043
$CaCO_3$	*0.160* 9.395	bi. 0.440	bi. 0.525	0.14	0.15	CaO .09747
$CaCl_2$				.13	.93	
$CaSO_4$	*2.988* .051		.121	.15	.76	
Fe_2O_3	Tr.			.01		.00382
$FeCO_3$		bi. .273	bi. .039			
Li_2O						Tr.
$MgCO_3$	*7.183* .121	bi. .327	bi. .180			MgO .0593
$MgCl_2$				.87	1.25	
K_2CO_3			bi. .077			K_2O .00421
SiO_2	*.584* .010	(b) .011	.086			.01972
NaCl	(c) *.680* .016	(c) .086		5.49	16.16	
$NaCO_3$	(c) *.838* .014		bi. .090			Na_2O .02784
SO_3						.02077
Cl						.024
P_2O_5						.00073
Organic			.011			
Total solids	*21.608* .372	1.087	1.079	6.29	19.26	.4081
CO_2			13.5 cu.in.			.36635

a Included with SiO_2. b Including Al_2O_3. c Including the corresponding potash salt.

No. 226. Owosso, city supply wells. Dearborn Drug and Chemical Works, analyst, for E. F. Dudley. This analysis checks quite closely with No. 100 by Kedzie; No. 227 is somewhat stronger, more like the Eaton Rapids waters, and very like the Leslie magnetic, No. 228, and is, therefore, probably from a well in the Coal Measures.

No. 227. Owosso, chalybeate. Given by A. C. Peale, Bull. U. S. Geol. Survey No. 32, p. 149.

No. 228. Leslie magnetic wells. Given by Peale, op. cit., R. C. Kedzie, analyst. There are a number of flowing wells in the Coal Measures, both at Owosso and Leslie, from which the two analyses just mentioned probably come.

No. 229. Section line between sections 2 and 11, Chesterfield Township (T. 3 N., R. 14 E.). From report of Douglas Houghton, State geologist, 1838, p. 29, and Winchell, 1861, p. 186. Sp. gr. 1.0057. Compare the Salutaris (No. 310), Wales (No. 122), Utica (No. 225), and Birmingham (No. 285) analyses, waters of the Berea grit.)

No. 230. Sanford. Sec. 25, T. 15 N., R. 1 W. This very old analysis is probably of water from the brine salt well, and the amount of earthy chlorides seems likely to be erroneous. Sp. gr. 1.0122. Same references as No. 229.)

No. 231. Hudson "Zauberwasser." Analyzed for Dr. George Chapman by A. B. Prescott in 1881.

The total of the bases and acids amounts to 0.62454; this excess over the total solids as given, which is the residue found constant at 220° F., is mainly accounted for by the free CO_2 (0.26795 parts per thousand).

WATERS FROM [illegible] ABOVE THE MARSHALL FORMATION.

Constituents.	[illegible] Sulphate.	[illegible] Sulphate.	[illegible] Sulphate and Chloride.	[illegible] Sulphate and Chloride.	[illegible] Sulphate and Chloride (sodic).	[illegible] Sulphate and Chloride (mixed).
$CaCO_3$	[illegible]	[illegible]	[illegible]	[illegible]		
$MgCO_3$	[illegible]	[illegible]	[illegible]	[illegible]		
$FeCO_3$			[illegible]			
Na_2O		[illegible]		[illegible]		
MgO	[illegible]		[illegible]	[illegible]		
$MgSO_4$		[illegible]				
KCl				[illegible]		
$NaCl$		[illegible]				
Na_2SO_4	[illegible]	[illegible]		[illegible]		
Organic	[illegible]				[illegible]	[illegible]
Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Temporary hardness	[illegible]					
Permanent hardness	[illegible]					

Constituents.	[illegible] Lansing.	[illegible] Lansing (sulphate with Rockwell).	[illegible] Lansing (sulphate with Rockwell).	[illegible] Lansing (Amer[illegible] cation spring.)	[illegible] Lansing (magnesia spring).
$CaCO_3$	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]					
[illegible]					
[illegible]				

Analyses Nos. 232 to 240 were all prepared by R. C. and F. S. Kedzie, except Nos. 236 and 237, the averages of partial analyses by a class of ten of their students, and No. 233, which was made by A. B. Prescott. No. 232 was given incorrectly in Geological Survey Michigan, Vol. V, Part II, 1895, page 32. The sample is from a well near the Bayport Hotel, and the analysis is given inaccurately on its circulars. The well goes down 15 feet into a bed said to be sandstone, which must be one of the sandstones associated with the Bayport limestone of the upper Grand Rapids series, since the outcrops on the bluff near by are limestone.

No. 233 is of water from the Bayport station, September 19, 1891. Analyst, A. B. Prescott, for W. L. Webber. Reaction faintly alkaline. The residue of half a liter was tested for K, Li, and Br. Saline solids determined directly were 0.5006 per thousand.

These two analyses resemble each other in the small amount of magnesia. The Bayport limestones are usually quite low in magnesia.

No. 234 is of water from the Agricultural College well, October 9, 1891. Furnished by Professor F. S. Kedzie.

No. 235 is an analysis of water from the same well, cited in an article on boiler water purification by Prof. R. C. Carpenter (Transactions Am. Soc. Mech. Engineers, Vol. XI, p. 939), in which the well is said to be 260 feet deep. As a matter of fact, Professor Weil assures me that but one well, 470 feet deep, has been used. Another well, just sunk (1899) to 325 feet, found flowing water at a less depth. Professor Carpenter probably refers to depth of chief stream. L. J. Lincoln's record of the well and a full history of it are left to a later paper. It probably draws water both from the Marshall and beds above.

No. 236 is of the same water drawn from the hydrant, and is the average of analyses by ten students.

No. 237 is of water taken from the purifier, and shows the effect of aeration and heating nearly to boiling in precipitating the lime and reducing the hardness.

Nos. 235 and 236 agree well in total solids, and the variation in No. 234 is probably due partly to different conditions of pumping and partly to different points of sampling. Analyses 172A and 172B in the Appendix show that such variations make appreciable differences.

No. 238 is of the Lansing city supply, which is obtained from wells of various depths, 40 to 150 and more feet deep. It is one of a series of analyses made every year by Professor R. C. Kedzie. The analyses are all similar, though the total solids may be as low as 19 grains per gallon. This analysis was made July 3, 1893, and indicates very good water. It is hard, however, and was so heavily bicarbonated that toward the end of the system dead ends of the pipes became highly charged with iron.

No. 239 is of water from an artesian (i. e., flowing) well in Lansing, which is not specified. There are a number of wells, generally about 200 feet deep, which have flowed. (See records in a later paper.)

No. 240 is of water from the deep well of the condensed-milk factory at Lansing, the record of which is known, so that it is certain that none of

[illegible] Hendall water is included among the same to other wells. The water is probably almost entirely from the Trenton [illegible]—Dayton [illegible]—as the relatively high percentage of lime shows.

No. 261 is an analysis made in Chicago in 1890, of water from the [illegible] mineral well of Lansing. It is still advertised as 1,002 feet deep, [illegible] was the original depth of the well. I am informed, however, that the water was originally quite salty; that the well is plugged about 50 feet down, and could probably only 37 feet—just to hard rock. Before I had learned these facts, however, this analysis and No. 262 were sufficient to show such a state of affairs, for waters so strong in lime, relatively to salt, point to the limestones as partially their source. The [illegible] is added artificially.

No. 263 is an older analysis by Dr. Jennings, taken from Poole, Bulletin U. S. Geological Survey No. 30, page 168. It is from the same well as the water of analysis No. 261, which has been variously known as Lansing magnetic, Michigan Congress, and Americanus. The casing and plugging may, however, have varied.

[illegible] HAPPIN, MIDLAND, PORTSMOUTH, BAY CITY, AND SAGINAW SPRINGS AND WELLS.

Constituents.	261. Poole well.	262. Hendall spring.	263. Lansing well.	264. Bay spring.	265. Saginaw spring.	266. Midland magnetic spring.	267. Midland mineral spring.
[illegible]						[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total solids	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	22.22	15.36	[illegible]	15.95	17.15	[illegible]	[illegible]

Constituent.	250. Midland.	251. Portsmouth (664-foot well).	252. Bay City (Gillmore 505-foot well).	253. East Saginaw (575-foot well).	254. East Saginaw (617-foot well).	255. East Saginaw (617-foot well).
$CaCO_3$	0.8924	.....	.....	.....	.....	.....
$CaCl_2$	.....	3.472	5.302	.....	.....	5.37
$CaSO_4$	.5832	4.884	3.961	.....	.....	2.25(?)
$Fe_2O_3 + Al_2O_3$	.320	.....	.....	.....	.....	.....
$MgCO_3$	.005	.....	.....	.....	.....	.....
$MgCl$	.....	4.333	4.115	.....	4.41	12.41
$MgBr$	.....	.....	.....	.....	Erroneous.	.....
KCl	Tr.	.....	.....	.....	.....	.....
SiO_2	.19	.....	.....	.....	.....	.....
$NaCl$	7.373	125.315	152.674	139.0	194.4	190.88
Total solids	9.0778	138.004	166.052	158.2	.....	210.91

Analyses Nos. 243 to 247 are of waters from a group of wells in Eaton apids. A record of the strata met in one is on file and will be given a later paper, but the chemical variation in the waters indicates that ere must have been some differences in casing or depth at the time e analyses were made. These are taken from Peale (op. cit., page 7).

No. 243 is of water from the Frost well; S. P. Duffield, analyst.

No. 244 is of water from the Mosher spring (i. e., flowing well?); . C. Kedzie, analyst.

No. 245 is of water from the Sterling spring or flowing well; C. T. ckson, analyst.

No. 246 is of water from the Shaw spring or flowing well; R. C. Kedzie, alyst.

No. 247 is of water from the Bodine spring or flowing well; R. C. edzie, analyst.

The large amounts of carbonate of lime and iron are characteristic of e waters of these wells. Nos. 227 and 228, waters from Owosso and slie, will be recognized as belonging to the same group, although jective evidence of the fact is weak. The Lansing and Midland alyses (Nos. 241, 242, 248, and 249) all have the same character. The esence of potash is less uniformly noted, but this may be due to fective analyses. The fire clays of the Coal Measures are, however, ry low in potash, so that one could not expect to find this element evalent in the mineral waters. Perhaps it has been leached out to the mineral waters, and the concentration previous to the formaon of the Coal Measures which deposited the gypsum of the Grand apids series may have left the potash more than usually abundant terwards.

No. 248 is an analysis of the Midland magnetic water, cited by ale (op. cit.), and is probably from the same well, possibly differently sed, as the water of the following analysis, but most likely is merely

a different version of the same analysis, as only the K_2SO_4 differs materially in the two analyses.

No. 249 is an analysis by Dr. S. P. Duffield of water from the Midland mineral springs. Well said to be 400 feet deep and probably cased 200 feet deep, i. e., to bed rock. These should be compared with other analyses of wells of various depths at Midland. The discussion of the rock records and varying salinity of the waters at Midland must be left to a later paper.

No. 250 is of the overflow water of the casing of the Midland Chemical Company's well No. 3, January 20, 1895. Analyst, J. E. Graves. The stream of water which has forced itself up outside the casing and, overflowing, yielded the sample analyzed, is supposed to come mainly from between 300 and 600 feet in depth, i. e., from the upper Coal Measures at about the level from which samples Nos. 248 and 249 were taken. The temperature as given, 55° F., agrees with this. On November 2, 1897, qualitative tests of this water showed a specific gravity of 1.030. Tests of water flowing from abandoned salt wells gave—from Foster's Block—specific gravity 1.012; and from 1¾ miles west of town 1.014, all overflowing with a strong current, and strong in salt and sulphates. Presumably, therefore, No. 250 is very largely but variably from lower levels than Nos. 248 and 249.

No. 251 is of water from a Portsmouth (part of Bay City) 664-foot well, with a 54° salinometer brine. Analyst, C. A. Goessmann. This and the following analysis are commercial analyses taken from Geological Survey Michigan, Vol. III, Pt. I, page 182. They serve to show that the tendency to a high percentage of sulphates continues to be characteristic of the waters above the Marshall, even in the deeper brines which have been used for salt manufacture.

This fact, so far as I know, was first remarked by Garrigues, from whose report the analyses are cited, and is entirely natural in view of the prevalence of gypsum in the Grand Rapids series, and of pyrite in the coal.

No. 252 is of water from the Gillmore well, 505 feet deep, at Bay City. Analyst and authority, same as for No. 251. Strength, 65° salinometer.

Nos. 253 to 255 are cited from A. Winchell's report of the State geologist, 1861, and are of water from the first salt well sunk by the East Saginaw Salt Company.

No. 253 is of the water when the well was 575 feet deep. Specific gravity, 1.110; 64° salinometer. Analyst, Dr. Chilton. 1,155 grains of solids and 1,014.57 grains of NaCl in a wine pint. (Op. cit., p. 170.

No. 254 is of the water when the well was 617 feet deep. Specific gravity, 1.172 grains; 86° salinometer. Analyst, Dr. I. G. Webb. 1,416 grains of NaCl and 32 grains of other chlorides in a wine pint.

No. 255 is of the same water as No. 254, and by the same analyst.

It is hardly worth while to reproduce all Dr. Houghton's analyses of

ine spring waters in his report of 1838, because of their early date. In uron County the boundary of the sulphated waters above the Marall is very sharp, the change from waters giving a strong reaction r sulphates to those giving no reaction coming within a mile. In the uthern part of the coal basin gypsum deposits are not struck in the ells and the waters are less sulphated, being chalybeate carbonated aters low in magnesia, not unlike those from the drift.

WATERS FROM THE MARSHALL FORMATION.

Constituent.	256. Badaxe No. 1.	257. Badaxe No. 2.	258. Grasmere.	259. Oak Grove.	260. Bayport. 328-foot well.	261. Old Bayport well.
Al_2O_3						
$CaCO_3$			.171	bi. *14.053* .241	bi. *2.2141* .038	*26.5263* .454
$CaCl_2$			Cl.0025			
$CaSO_4$		0.0		*13.703* .234	*25.6405* .440	*20.9812* .360
Fe_2O_3				Al_2O_3 *.583* .01		
$FeCO_3$					*.9570* .044	
LiCl				Tr.		
$MgCO_3$				bi. *12.145* .208	bi. *5.8245* .100	
MgCl				*1.253* .021		*11.5630* .198
$MgSO_4$						
KCl				*2.973* .051		
SiO_2				Tr.	*.8412* (a). 144	*.8598* (a) . 015
NaCl				*98.363* 1.685	*53.9742* .925	*138.7109* 2.379
$NaCO_3$					*11.7249* bi. .201	
Inorganic	*16.45* .235	*14.30* .204				
Organic	*7.000* .100	*6.300* .090				
Total solids	*23.45* .335	*20.650* .295		*143.075* 2.506	*110.4764* 1.892	*198.6412* 3.403
Hardness	5°.9	5.4°	10.°			
Free ammonia	.0000024	Slight tr.				
Albuminoid ammonia	.000072	.000048				
Loss						

a Silicic acid.

It is not at all certain that water above the Marshall is not admitted o many of the wells represented in these analyses. Even where the

upper water is supposed to be cased off there may be leaks in the casing. As a whole, however, the analyses show very well the characteristics of the formation. One feature which deserves special attention is the freshness of these waters—i. e., low amount of mineral matter for a given depth—compared with those of other horizons.

No. 256 is of the Badaxe water supply, which comes from artesian wells, whose record is known, over 200 feet deep in the Marshall. Partial analysis by F. S. Kedzie in 1897. This and the following analysis were made because of complaint regarding the excessive growth of algæ. This sample was taken at the pump, while sample No. 257 was taken from the dead end of a pipe. In this respect they correspond to 172A and 172B. In both cases, the sample taken farthest from the pump contains the greater amount of matter, both organic and inorganic. Suggested remedies are frequent—flushing and covering the standpipe so as to exclude light. F. S. Kedzie also suggested that the reaction of $CaSO_4$ with organic matter might produce H_2S and add to the disagreeable character of the water, but it is doubtful if $CaSO_4$ exists appreciably in the Badaxe water. Qualitative tests failed to reveal it.

No. 258, Grasmere, is of water "from a coarse-grained gray sand rock reached at 40 feet and extending 138 feet, rising to 8 feet above the surface." Analyst, A. B. Prescott, for W. L. Webber. Qualitative tests showed Ca, Mg, Na, Al, SO_3, CO_2, Fe not more than a trace.

No. 259 is of water from the Oak Grove mineral well at Flint, 265 feet deep, flowing about 9 gallons per minute. Analyst, J. E. Clark. Original statement in grains per United States gallon. There are only 39 feet of casing, and water comes in above the Marshall, as the amount of $CaSO_4$ shows.

No. 260 is of water from a well 328 feet deep near the Bayport House, Bayport. A. B. Prescott, analyst for W. L. Webber. The water said to be found in a coarse gray sand rock (upper Marshall) at the bottom (below 250 feet), but the analysis indicates that the upper waters are not altogether excluded. This is the flowing well just north of, but quite a little below, the hotel. The temperature of 47° F. is said to be the same throughout the year. Specific gravity, 1.0017. Reaction faintly alkaline. Analysis, as given in table, as combined from CaO 0.1933, MgO 0.0421, NaO 0.5583, FeO 0.0027, SO_3 0.2582, Cl 0.6389, CO_2 0.1264, SiO_2 0.0111, total 1.8310. A similar well lies close to the bay and just west of the railroad track.

No. 261 is of water from the Old Bayport well. This was a well for salt, 1,900 or more feet deep; when plugged at 750 feet the water was still salt, but when plugged at 550 feet it was a potable water, presumably the one analyzed. Analyst, A. B. Prescott, for W. L. Webber. Reaction faintly alkaline. Specific gravity, 1.0029. The constituents are combined from CaO 0.2978, MgO 0.0835, NaO 1.2900, SO_3 0.2110, Cl 1.5850, CO_2 0.2358, SiO_2 0.0113, total 3.7144.

No. 262 is of water from Butterworth's magnetic spring, Grand Rapids. S. P. Duffield, analyst. Mr. Powers says that this well draws mainly from the upper 18 feet of the Marshall sandstone—i. e., 261–274 feet of the record given by Winchell—and that the water contains more $CaCl_2$ than the water of his well—the Arcade—which draws from the lower 18 feet of the Marshall—i. e., 295 to 300 feet from the surface. This would apply better if we took No. 262 to be the analysis of the Arcade well water, low in $CaCl_2$, and No. 263 to be the analysis of water from the top of the Marshall, from which, indeed, it is derived. The constituents other than the NaCl and the $CaCl_2$ are remarkably similar.

No. 263 is of water from the original test well, Scribner's, at Grand Rapids, October 14, 1859. Analyst, Prof. L. R. Fisk. Specific gravity, 1.01752. Biennial report of State geologist, 1861, pages 146, 167, 186, and Geological Survey Michigan, Vol. III, Part I, page 180. The water at 248 feet depth is reported as fresh, but there are saline streaks at 82 feet and at 140 feet, so that probably most of the salt, etc., comes from that section.

Nos. 264 to 266 are of waters from wells within a few miles of each other, analyzed by the same chemist, and, as the record of one and the date concerning the others show, drawing chiefly on the Marshall sandstone at 179 to 250 feet depth.

No. 264 is from Peale, Bulletin U. S. Geological Survey No. 32, page 148.

No. 265 is from Peale, loc. cit. I also have an independent version of the analysis, giving 0.1808 bicarbonate of lime; trade name, "Attapah;" specific gravity, 1.0064. Temperature, 52° (Peale), or 50° F.

No. 266 is also taken from Peale, or from Geological Survey Michigan, Vol. V, Part II, 1895, page 60. Temperature, 48°.

I would not lay too much stress upon the presence of Br, Li, etc., in the foregoing group of analyses, for much depends on whether the chemist looked for them. Yet the presence of bromine is interesting in connection with its undoubted presence in abundance in the Marshall brines of the center of the basin. The absence of $CaSO_4$ is noteworthy, also the prevalence of chlorides and bromides of calcium and magnesium over other salts.

Constituent.	262. Grand Rapids (Butterworth).	263. Grand Rapids (original).	264. Grand Haven.	265. Springlake (Attapah).	266. Fruitport (iron magnetic).
Al_2O_3	0.007	.....	0.009	Tr.	Tr.
NH_4Cl	.....	.....	.....	0.0003	.....
$CaCO_3$	.143	0.0473	.035	bi. .002	bi. 0.087
$CaCl_2$	.010	2.764	2.557	1.944	1.903
$CaSO_4$	1.288	1.312	.....	.....	.....
CaF_2	.....	.....	.001 (?)	.....	.....
$FeCO_3$	.017	.0145	.001	bi. .017	bi. .129
Li_2CO_3	.....	.....	.....	Tr.	.....

Constituents	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]			[illegible]	[illegible]	
[illegible]			[illegible]		
[illegible]				[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]			[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
[illegible]			[illegible]	[illegible]	
[illegible]		[illegible]		[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]			
[illegible]	[illegible]				

[illegible]

SAGINAW RIVER SALINE WELLS.

Constituents	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]					[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
[illegible]					[illegible]		
[illegible]							
[illegible]							
[illegible]						[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
[illegible]							
[illegible]					[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
[illegible]							
[illegible]							
[illegible]							
[illegible]							

Analyses No. 267 et seq. show much stronger waters. Such a shaft line does not exist in nature, but is due merely to the fact that saline waters either weak enough to be drinkable or as strong as possible

No. 267 is of water from the East Saginaw Salt Manufacturing Company's well when 806 feet deep. Analyst, C. A. Goessmann. October, 1867 Geological Survey of Michigan, Vol. III, 1876, Part I, page 18. *Total* obtained by addition.

No. 268 is of water from Swift & Lockwood's well, 860 feet deep, at Saginaw. Same analyst and date as No. 267. Total obtained by addition.

No. 269 is of water from the East Saginaw Salt Manufacturing Company's well when 636 feet deep. Prof. S. H. Douglass, analyst. April 11, 1860. Same reference as No. 267, and also biennial report of the State geologist, 1861, pages 171 and 186. Total obtained by addition. April 16, specific gravity, 1.170. As No. 269 is stronger than No. 267, which is of a water with deeper source, an admixture of the upper waters—that is, leaky casing when the water for No. 267 was drawn—is suggested, especially since the weaker water is stronger in sulphates.

Sample No. 270, from Saginaw River, specific gravity 92°, was left for an analysis, not yet reported, by T. N. Whittier.

No. 271 is an analysis of the same water as Nos. 267 and 269, the well being 649 feet deep. Analyst, Dr. Chilton. May, 1860. Reported by W. L. Webber in the biennial report of the State geologist, 1861, pages 171 and 186. It agrees quite well with previous analyses and reports, the bromides probably overlooked by the others. Total directly observed.

No. 272 is of water from the well of the Oneida Salt Company, Crow Island, Zilwaukee. Analyst, H. C. Hahn. Geological Survey of Michigan, Vol. III, Part I, page 185. Total directly observed.

No. 273 is of water from the Bangor Salt Manufacturing Company's well at Banks, Bay City. Well 774 feet deep. Analyst and references the same as No. 267.

BRINES OF THE MARSHALL SANDSTONE.

Constituent.	274. Michigan Solar Salt Co., Zilwaukee.	275. Buffalo Salt Mfg. Co., East Saginaw No. 1.	276. Buffalo Salt Mfg. Co., East Saginaw No. 2.	277. New York Solar Salt Co., Zilwaukee.	278. A. L. Clark's well, Big Rapids.	279. Bay City No. 1.	280. Bay City No. 2.
$CaCO_3$	0.010	.....	.....	0.010	.....	.....	.....
$CaCl$	29.16	24.106	24.321	30.40	46.40938	33.878	32.556
$CaSO_4$	.82	1.028	1.038	.73	.47316	.689	.691
$FeCO_3$	.123	.119	.123	.058	.06354	.856	1.292
$FeCl_3$	.....	.....	.....	.038	.....	.....	.....
$MgCO_3$	.015	.....	.....	.006	.....	.....	.....
$MgCl$	13.81	10.803	8.744	14.19	19.79204	13.783	13.779
$NaBr$	.....	Tr.	Tr.	1.2374	1.2374	.....	.....
H_2SiO_3	.....	.....	.....	.....	.00108	.....	.....
$NaCl$	196.71	187.764	189.472	199.14	185.69219	202.945	204.204
Organic or loss	loss 2.20	21.104	21.226	5.02	.....	14.518	14.147
Total solids	242.85	a 244.924	(b)	c 249.58	d 253.66878	a 366.669	(b)
Degrees salinometer, or specific gravity	1.1900	1.1771	.....	1.1930	1.205	1.1989	.....
CO_2	.....	.....	.....	.....	.....	.....	.....

a Average of No. 1 and No. 2. b See No. 1. c Direct determination. d By addition.

No. 274. Michigan Solar Salt Company, Zilwaukee. Analyst and references the same as No. 272.

No. 275 and No. 276 are duplicate analyses, cited from the unpublished thesis "Saginaw Salines: a short sketch of their history and source; of the methods of obtaining them; of the processes used in the manufacture of salt from them; together with analyses of representative specimens," by John Ayres, Ann Arbor, June, 1880, of which an abstract from the copy in the general library of the University of Michigan was made for me through the kindness of Professor Prescott. For this analysis and probably the others by Mr. Ayres the specific gravity was taken at 20° C., the total residue by drying at 110° to 115° C. In No. 275 the total Cl in 25 cubic centimeters brine was 4.043.

No. 277 is of water from the well of the New York Solar Salt Company at Zilwaukee. Analyst and reference the same as No. 272.

No. 278 is of water from the Red Cross well at Big Rapids, A. L. Clark original owner. Depth, 1,400 feet. Analyst, A. B. Prescott. The published statement is in grains per United States gallon at 62° F.—i. e., United States gallon=70,277.19 grains. The following is the statement of bases and acids: NaO 98.95923, MgO 8.35636, CaO 3.66594, FeO 0.03944, SiO_2 0.00073, Cl 156.97050, Br_2 0.96057, SO_3 0.27833, CO_2 0.02415=289.23289, which, less oxygen not in the salts and plus the water of silicic acid 35.56590, gives the tabulated footing.

A sample from a drug-store gave specific gravity 1.156 with 0.75 Br. When I tested it, December, 1895, the specific gravity was 1.202. The water is said to have been struck at 1,300 feet and to have had at first the specific gravity 1.229. The mineral strength is thus lasting very well.

Nos. 279 and 280 are duplicate analyses of representative Bay City brine, obtained through S. S. Garrigues. Analyst and reference the same as No. 275. In 25 cubic centimeters brine was 4.6496 Cl.

BRINES AT MIDLAND.

Constituent.	281. Midland No. 1.	282. Midland No. 2.	283. Midland bittern No. 1.	284. Midland bittern No. 2.
$CaCl_2$	86.666	88.760	143.574	145.859
$CaSO_4$	.199	.220	.160	.160
$FeCO_3$	1.144	.954	.....	.....
MgCl	24.665	24.109	39.263	34.019
$MgBr_2$	8.771	8.771	48.356	48.356
NaCl	148.984	147.599	56.754	60.801
Total solids	304.750	366.059	.....	.....
Loss	34.321	34.337	77.952	76.864

Nos. 281 and 282 are duplicate analyses of Midland brine, Harris Brothers' well, 1,300 feet deep, flowing 30 gallons a minute. Analyst and reference the same as No. 275. In 25 cubic centimeters brine was .2340 Br and 5.0414 Cl. See also Geological Survey Michigan, Vol. V, Part II, page 69. The specific gravity and total solids do not seem accordant, since the total solids would imply a higher specific gravity. The Larkin & Patrick well at the same depth is said to have had strength of 115° salinometer (1.239 specific gravity), and the Dow (Midland Chemical Company) well has 1.235 specific gravity.

Nos. 283 and 284 are of bittern left after the crystallization of salt from the same well as Nos. 281 and 282. Same analyst and reference. Published also by Rowland, Tenth Census of the United States, Vol. I, p. 22. See also Geological Survey Michigan, Vol. V, Part II, page 35, and note corrected NaCl. In 25 cubic centimeters was 1.32 Br and .8869 Cl. "In the estimation of Br by Mr. Ayers, this element was expelled by treatment with excess of chlorine during evaporation to dryness, then obtaining the total of silver chloride in ratio of the weight of mixed silver chloride and bromide from the brine"—not a very accurate method. Note the large amount of loss when total solids are independently and directly determined. This shows that ammonium and potassium chlorides and other constituents have not been determined. Potassic chloride is made from the Marshall brines by the North American Chemical Company at Bay City. Mr. Ayres's chemical work was done under Prof. H. W. Cheever about three years before the writing of "Select methods of qualitative analysis."

An analysis of the water from the Alma Sanitarium Company's well was made by Prof. C. A. Davis, May 5, 1889. Said to be almost a pure Marshall sandstone water. The published form was inaccurate, and I am not able to give corrected figures. The analyses given in a later section (Nos. 325 to 327) show the lower water and the two waters mixed.

In the above group of analyses the characteristics of the Marshall waters are well defined—i. e., the excess of Cl so as to be far more than to satisfy the soda; or, as Garrigues says, a "decrease in percentage of gypsum, an increased percentage of the earth chlorides, and an increased quantity of salt."

Numerous qualitative tests have convinced me that the sulphates are often from higher beds, and for a given depth the Marshall is less mineralized than the beds above or below. It is not charged with gases to any marked extent.

As soon as we leave the porous upper Marshall and get down to the boundary between it and the Coldwater—that is, the lower Marshall—the beds are likely to become saline again. For instance, S. O. Hickok, of Allen, Hillsdale County, Michigan, has a well 221 feet deep, which yields 277.04 grains NaCl and 33 of $CaSO_4$ per gallon. I have numer-

ous other qualitative tests that show the same thing. But on the whole, between the Marshall and the Berea grit the strata are dry and the waters do not merit a separate section.

WATERS FROM THE BEREA GRIT.

Constituent.	285. Birmingham.	286. Ann Arbor.	287. White Rock.	288. East Tawas.	289. Port Austin.	290. Sand Beach.	291. Oscoda.
$CaCO_3$	0.10205						Tr.
$CaCl_2$		24.53	5.373	34.843	31.274	3.000	42.100
$CaSO_4$			2.623	.350	.129	2.539	Tr.
$FeCO_3$	.0049	*a* 4.381	*b* .0032				
$MgCO_3$	.0645						
$MgCl$		6.95	4.106	12.433	15.675	1.591	19.3
KCl	.03156						
SiO_2	.0206						
$NaCl$	2.27256	138.96	189.102	156.141	176.161	225.673	179.300
Na_2CO_3	.15558						
$NaNO_3$	.00122						
Organic	.03546						
Total solids	2.70453	174.8	201.236	203.767	223.239	232.803	241.9
Salinometer		68.°	78.5°	85.°	88.°	284.°	90.°

a As oxide? *b* FeO.

The well at Utica, with 2.226 ounces per cubic foot solids, probably obtains water from the Berea; the only sample of potable water, however, of whose geological horizon we are certain, independent of the analyses, is No. 285. Kedzie's analysis of the Wales water comes next. Some idea of the composition of the Berea brine at Ypsilanti may be obtained by comparing the analyses of the Ypsilanti wells (Nos. 304 and 305), in the first of which the higher water is cased out and in the second admitted. We see that the water from the Berea is extra strong in NaCl and is a very pure brine.

No. 285 is of water from the new well on the farm of J. R. Cooper, Birmingham. No. 2, about 1,500 feet southwest of the first well, which was about 20 feet above the swamp, the water rising to about 16 feet from the top; No. 1 also contained more chlorides and less carbonates.

There is an excess of CO_2, probably in the form of bicarbonates, present in the water, and the organic matter and loss does not include this, but does include the CO_2 with the iron. Analyst and informant, George L. Heath.

No. 286 is of water from the Ann Arbor deep well, of which there are two accounts. According to Rominger (Geol. Survey Michigan, Vol. III, 1876, Part I, p. 92), the brine from the sandstone 333 feet down—i. e., from the Berea grit—has a specific gravity of 1.142, and 19 per cent residue by evaporation, "almost pure chloride of sodium." Winchell, in his Geology of Washtenaw County (Chicago, 1881, p. 26), gives the strength as 68° salinometer, corresponding to a specific gravity of 1.131 and 17.48 *per cent salt;* he also gives an analysis of the residue, and putting the

two together we obtain the figures of the tabulated analysis. Illuminating gas also escapes, and is also reported from a well at Blackmar which reaches this horizon.

No. 286A of the Appendix is a recent analysis, by J. E. Clark, of water from the Ypsilanti Sanitarium, and is so pure a solution of sodic chloride that the lower water must now be almost entirely eliminated.

No. 287 is of brine from Thompson Bros.' 566-foot well at White Rock, Huron County, and is cited from Vols. III and V of the Geological Survey Michigan, as are also the remaining analyses of the section. The analysis, however, is corrected and the iron added from a statement in the report of the Commissioners to the Centennial Exposition of 1876 at Philadelphia. The specific gravity is there given as 1.155.

No. 288 is of brine from Grant & Co.'s 908-foot well, East Tawas. References as for No. 287.

No. 289 is of brine from Ayres & Co.'s 1,198-foot well at Port Austin, Huron County. References as for No. 287, and also Hunt in Geological Survey of Canada, 1866–1869, p. 220.

No. 290 is of the brine from Jenks & Co.'s well, Sand Beach. S. P. Duffield, analyst. G. W. Jenks reports that 98.7 per cent of the solids was NaCl.

No. 291 is of brine from Smith, Kelley & Dwight's 1,070-foot well at Oscoda. Same references as No. 287.

No. 291A of the Appendix is an analysis of the Berea brine where it is struck, at a depth of 2,200 feet, at Bay City, near the center of the basin, and even at this depth it has no more $CaCl_2$ than the much less deep-seated brines of Midland and Mount Clemens.

That this Berea brine is a purer solution of NaCl than the brines immediately above or below is shown not merely by comparing the Ypsilanti analyses and the analyses in general, but by such facts as when Frank Crawford's well at Caseville, which had been drawing from the Berea at 1,760 feet, was deepened to 2,270 feet it became necessary to clean the pans twice as often.

WATERS FROM BEDS BELOW THE BEREA GRIT.

When wells pass through the Berea and go through the Devonian black shales they usually encounter no water until near the bottom of the Devonian. It would be interesting, if possible, to sort out those wells which draw merely from the limestone of the Traverse (Hamilton), those which tap the upper Helderberg or Corniferous, a very well-marked horizon, and those which go deeper into the lower Helderberg and Salina; but this does not seem practicable at present, for in the southern part of the State the Traverse formation is less than 100 feet thick, and there has been little attempt, so far as I have record, to isolate the various brines. I suspect, however, that such determination might lead to important economic results, as in some of them rare elements, like K, Br, and Sr, may be richly contained. At the outcrop of

the lower Devonian limestones are the various sulphur springs mentioned by Peale and widely distributed in Monroe and Wayne counties (Erie, Shawnee, Wyandotte). For the northern part of the State the Harbor Springs' analysis (No. 53) may show what kind of water is taken into the rock. We have analyses showing very lightly mineralized waters from Charlevoix, Bay View, and Petoskey (Nos. 292, 293, 294). The Charlevoix waterworks well has probably not pierced through the (Marcellus?) shale at the bottom of the Traverse series, according to the record of the strata. On the other hand, the Petoskey well probably draws from the Dundee limestones. This well is located near the Chicago and West Michigan Railway station, and the surroundings are now somewhat changed. The view shows how they looked at the time of well drilling (Pl. III).

WATERS FROM DEVONIAN OR SILURIAN LIMESTONES.

Constituent.	292. Charlevoix.	293. Bay View.	294. Petoskey.	295. Frankfort.	296. Wyandotte.	297. Alpena No. 1.	298. Alpena No. 2.
$CaCO_3$	*5.27* .056	*11.00* .157	.....	.....	0.633	0.788	.....
$CaSO_4$	.....	*4.00* .057	*11.200* .160	1.220	1.274	.429	*a* .109125
Fe_2O_3	*4.331* *b* .074	*.50* .007	*.20* .003	.018	.004	.....	.....
$FeCO_3$	.....	.....	.....	.....	.....	.026	.....
$MgCO_3$	*.85* .015	*4.70* .067	.....	.090	.....	.899	.....
$MgSO_4$	.....	.....	*8.50* .121	1.100	.691	.....	.....
KCl	.....	.....	.....	Tr.	.....	.....	.....
K_2SO_4	.....	.....	*.57* .008	.....	Tr.	.....	.....
SiO_2	*.54* .008	*.60* .009	*.97* .014	.017	.....	(*c*)	.....
NaCl	*1.50* .023	*4.20* .060	*7.70* .110	.409	.327	.975	.00464
Na_2CO_3	.....	.....	.....	.....	.434	.225	.....
Na_2SO_4	*2.02* .035	*6.00* .086	.....	.580	.369	.....	.....
N	.....	.....	.....	.....	.....	*c* .240	.....
CO_2	.....	.....	.....	.....	.436	*c* 8.4	.....
H_2S	.....	.....	Tr.	*c* 44.5	*c* 20.00	*c* 35.36	19.02
Volatile at red heat	.....	*6.00* .086	*6.16* .088	.....	.....	.....	.....
Organic	.....	.....	.....	.....	.....	.013	.791
Total solids	*12.81* .212	*31.00* .442	*43.88* .629	3.433	4.191	3.399	3.060
Total hardness	.....	15.[illegible]	.....	.....	.....	.....	.....
Permanent hardness	.....	8.[illegible]	.....	.....	.....	.....	.....
Free ammonia	.....	.00002	.00006	.....	.....	.....	.00072
Albuminoid ammonia	.....	.00001	.00005	.....	.....	.....	.00174
Permanganate	.....	.....	.00020	.....	.....	.....	.004102

a All sulphates together. *b* As Al_2O_3. *c* In cubic inches per gallon.

Constituent.	299. Alpena No. 3.	300. Detroit (Riverside No. 1).	301. Detroit (Riverside No. 2).	302. Detroit (Riverside No. 3).	303. Ypsilanti No. 1.	304. Ypsilanti No. 2.	305. Ypsilanti No. 3.
Al_2O_3	.....	.....	.....	0.230	.....	.....	.....
$CaCO_3$	.....	0.281	0.191	2.556	0.6322	0.98181	0.90712
$CaCl_2$	.....	.....	.728	14.743	.....	2.45765	2.87328
$CaSO_4$	3.1314	1.968	2.756	30.702	3.0802	3.01121	2.98794
$FeCO_3$	.....	.....	.002	.....	Sl. tr.	Tr.	.02856
$MgCO_3$	.....	.....	.004	.193	.....	.....	.....
$MgCl_2$	1.3417	.445	1.882	.....	.9911	2.19596	2.63344
$MgBr_2$	.....	.....	.....	.....	.0610	.188	.....
$MgSO_4$	.....	.759	.....	18.549	1.1659	1.774	1.94260
KCl	.....	.....	.....	.003	.....	.....	.....
KBr	.....	.....	.....	.....	.....	.....	.26764
K_2SO_4	.....	.....	.....	.....	.2330	.6058	.....
NaCl	4.1835	.554	5.320	58.460	14.241	20.97644	36.94436
Na_2CO_3	.0283	.....	.048	.....	.....	.....	.....
NaS	.4812	.....	.....	.....	.2087	.1445	.....
SiO_2	.....	Tr.	.003	.060	.0240	.3398	.43910
Total	9.1677	3.997	10.941	a 132.442	20.6362	38.6788	49.11404
H_2S	.1267	b 19.02	b 14.77	6.946	b 21.0786	b 32.216	b 35.84

a Sum including H_2S. b In cubic inches per gallon.

No. 292 is of water from the Charlevoix waterworks well No. 2. Analysis obtained through H. P. Parmelee. Depth, 400 feet.

No. 293 is of water from the Bay View well. Depth, 498½ feet. Flow, 200 barrels an hour. Water likely to be roily. F. S. Kedzie, analyst. August 20, 1895. Well completed in July, 1895.

No. 294 is of water from the Petoskey well, 555 feet deep. Analyst, R. C. Kedzie. The two wells (analyses Nos. 293 and 294) are close together, but, as will be noticed on comparing their records, No. 294 has passed through and is drawing its water beneath a bed of shale, probably the base of the Traverse or the Hamilton, in which the Bay View well stopped. The Petoskey is apparently, therefore, a water from the Dundee (upper Helderberg), with the characteristic presence of H_2S, while the Bay View water is in the Hamilton.

No. 295 is of water from Butler's well at Frankfort. R. C. Kedzie, analyst. See Geological Survey Michigan, Vol. V, Part II, page 59, also plate. The temperature of 58° F., compared with the well record and statement that the main flow is at 1,400 feet, indicates that this water also is from the top of the Dundee limestone, with which its sulphated and sulphureted character is in entire accord.

No. 296, Wyandotte white sulphur springs, is of a similar water from the other end of the State. Analyst, Courtis. Cf. Peale, Bulletin U. S. Geological Survey No. 32, page 150. Generally the CO_2 is computed as bicarbonate.

No. 297, Alpena No. 1 (?), 1,164 feet deep, with chief flow at 600+ feet (?). Analyst, S. P. Duffield. Given by Peale as in grains per

United States gallon, but really per imperial gallon. The records of the first and second wells put down at Alpena seem to have been confused somewhat. See later paper; also Peale, Bulletin U. S. Geological Survey No. 32, pages 145, 147, Geological Survey of Michigan, Vol. III, Part I, page 39, and Vol. V, Part II, page 46. The temperature given by Peale, 52° F., nearly agreeing with my own observations, indicates a water about 500 feet nearer the surface than at Frankfort (900 feet), and Rominger says it is an "upper sulphur water," contaminated with a little salt from lower down. With this description both Nos. 297 and and 298 agree, and I found, by qualitative test at the well in 1897, markedly sulphated and sulphureted waters, with extremely little chlorine. The waters were then flowing naturally and not pumped, and this might give the upper water greater purity.

No. 298 is Vaughan's partial sanitary analysis of water from Alpena spring, so called because it is customary to speak of flowing wells as springs. The analysis doubtless refers to one of these wells. At any rate, in its strength in sulphates and extremely low Cl, it agrees with my qualitative tests of the wells. Brownish in color, with amoebæ, diatoms, algae, zoöglœa, several varieties of germs, and amorphous matter.

No. 299 is of water from Alpena well No. 3. Analyst, W. F. Edwards, of the Michigan University School of Pharmacy. Analysis probably made in 1892.

J. J. Mason & Co. report drilling wells 625 feet deep for the Northern Extract Company—water struck at 400 feet—which flow 450 gallons a minute and eat out the casing in about six years. These waters are merely "alkaline," whereas rock salt was struck at 1,200 feet in the Sanitarium well in 1893.

We next introduce a series of analyses of waters from wells bored in or near the Riverside bath house, corner West Fort street and South Clarke avenue, Detroit. There are said to be two wells, one more salt than the other. No. 302 is said to be of water from the two wells mixed; this can not refer to Nos. 300 and 301, but probably to No. 301 and another well put down later and still deeper. The temperature of 50° F. indicates no great depth for the wells from which samples Nos. 300 and 301 were taken, and they are not strong. No. 300 is like No. 297.

No. 300, Riverside magnetic mineral springs, Springwell's Fort, No. 1, is taken from Peale, Bulletin U. S. Geological Survey No. 32, pages 146–7, and is much like No. 296.

No. 301 is taken from Peale, Bulletin U. S. Geological Survey No. 32, pages 146–7, and is much like No. 296.

No. 302, Clark's Riverside bath house, Detroit. Depth of wells unknown. Analyst, S. P. Duffield. November 3, 1889. Cited from a pamphlet, where the analysis is given both in grains per imperial gallon and in parts per liter, the former figures being 700 times the latter. I give the latter figures multiplied by 10.

No. 303, Ypsilanti mineral springs. Depth 550 feet. Analyst, A. B. Prescott. Water drawn by his assistant March 31, 1883. Tempera-

ture, 58° F. (14.5° C.). Specific gravity at 15° C., 1.0163. Reaction alkaline. Total H_2S in volume at 58° F., 91.233 cubic centimeters. The analysis, dated May 5, 1883, is given in grains per United States gallon, not imperial gallon, as the same figures are given by Peale (p. 150), and grams per liter, the former figures being 58.37 times the latter. I give the latter figures, but, taking the specific gravity into account, the figures should be diminished by dividing by 1.063 in order to reduce to grams per kilogram, or parts per thousand. As has been noticed in connection with the Big Rapids analysis, Professor Prescott allowed for the specific gravity in stating the result in grains per gallon from parts per thousand, and has apparently done so here. But it is sometimes neglected, and I do not know how Shepherd, the analyst of No. 304, worked. I have preferred, therefore, to leave the Ypsilanti analyses as stated rather than to introduce a small and dubious correction.

This analysis (No. 303) is probably from the Cornwall mineral well or the original well (see fig. 1).

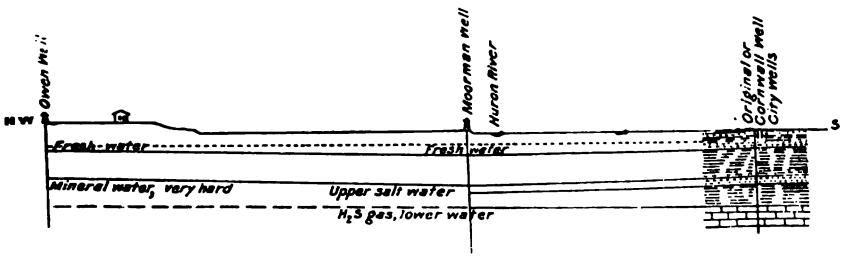


FIG. 1.—Section showing the relations of the deep wells at Ypsilanti to each other, to the wells of the city water supply, and to the several water-bearing strata.

The following is Prescott's statement of constituent acids and bases:

Total solids determined in grains	1205.6665
Hydrosulphuric acid, total in volume at 58.1° F. (14.5° C.)	91.2330
Total solids by evaporation	20.5800
Constituent bases and acids:	Grams per liter.
1. Potassa	0.1260
2. Soda	7.7120
3. Lithia	Tr.
4. Magnesia	0.8190
5. Lime	1.4865
6. Strontia	Tr.
7. Baryta	Slight tr.
8. Iron (ferrous oxide)	Slight tr.
9. Carbonic anhydride	0.3435
10. Sulphuric anhydride	2.6950
11. Hydrosulphuric acid	0.1321
12. Chlorine	9.3828
13. Bromine	0.0530
14. Fluorine	Slight tr.
15. Boric anhydride	Tr.
16. Phosphoric anhydride	Slight tr.
17. Silicic anhydride	0.0240
	22.7739
Deduction of hydrosulphuric acid and of oxygen displaced in the bromide, chlorides, and sulphide in excess over addition of sulphur in the sulphide and of water in the bicarbonate	2.1377
Total salts determined	20.6362
Total bases and acids determined	22.7739

No. 304, Ypsilanti Mineral Bath Company, Moorman mineral well. (See fig. 1.) Analyst, James H. Shepherd. Water drawn September 5, 1884. Temperature of water, 14.2° C. (57.5° F.); of air, 26.3° C. (79.3° F.). Specific gravity, 1.0280. Reaction, alkaline. The results cited are said to be in grams per liter, and are also stated in grains per imperial gallon, the latter figures being 70 times greater than those given (by which I have detected one or two misprints in the analysis as published in the pamphlet of the company; in Peale's paper also, op. cit., it should read 124.42 $MgSO_4$), and accordingly, though grams per liter are stated, parts per thousand may be meant, the imperial gallon being taken as 10 pounds. At the time this sample was taken the well was cased to 550 feet, to shut off all higher waters, and practically this is pure Dundee limestone water.

No. 305, water from same well as No. 304. Analyst, De Forest Ross, September 13, 1897. Temperature of water, 16.5° C. (?). Reaction, alkaline. Specific gravity, 1.0358. The pamphlet statement is in grains per imperial gallon. Before this analysis was made the casing was pulled back to 185 feet, so as to admit the upper stronger water of the Berea grit which is more predominant in No. 286A.

No. 306, T. C. Owen's well Atlantis, on the hill near the normal school at Ypsilanti. (See fig. 1.) Analysts, J. H. Shepherd and W. F. Pett, 1884. Peale, op. cit., page 150.

It will be noticed that No. 305 is the strongest water of the four, and that the addition of the Berea water has increased mainly the NaCl, while the sulphates have not increased in the same proportion. The relations of the three wells are shown in fig. 1.

The remaining analyses are for many reasons difficult to group. In the first place, the specific gravity is so great that parts per thousand—i. e., grams per kilogram—and grams per liter are by no means equivalent expressions. Yet chemists accustomed to analyzing waters whose specific gravity is practically unity, speak of grains per imperial gallon, when grains per unit of 70,000 grains or 10 pounds is meant. Others, like A. B. Prescott, are careful to apply the volume correction. Then, again, the specific gravity of a brine varies, at different temperatures, to a measurable, though trifling, extent (cf. analysis No. 323). Thus the reduction of the analyses to strictly comparable units is not easy. Again, one can not be sure in such analyses as are issued in advertising pamphlets whether care has been taken in proof reading, or even whether they have not been altered. A number of minor errors seem thus to have crept into Peale's list. Often the kind of gallon is not specified, and Peale's rule—to assume the United States gallon unless otherwise stated—is not safe. In fact, when most figures for different constituents are multiples of 7 the imperial gallon is probably used. Finally, as will be easily seen, the analyses vary considerably, and imperfections of analysis, though they may be considerable, are unimportant beside the larger ones due to variation, from time to time,

the quality of the water itself. A most important factor in this connection is the character and depth of the casing, as is seen in the Ypsilanti wells just described (analyses Nos. 304 and 305). The same thing is seen in the Alma analyses (Nos. 327 to 329), in all of which was the withdrawal of the casing admitted a different water. We do not know the condition of the casing in many instances, and, moreover, casing supposed to shut off an upper water does not always succeed in actually doing so. How far the great variations, for example at Mount Clemens, are due to the casings remains to be proved. Then, again, variations have been found which seem to be connected with the rate of pumping. There are very few waters on the list below that are not composite—made up of waters from various levels, and, as they come from beds of varying porosity as well as varying head, a well pumped nearly to its capacity will draw more largely from the more porous beds than when it is more gently pumped. In fact, a very porous bed with low head might, under heavy pumping, yield a large proportion of the water, which would yield none in the normal flow. Such are some of the considerations which we must especially keep in mind in studying the analyses from No. 232 on. There is still another consideration which is forced upon us by the first analysis to be described.

No. 307 is supposed to be of water from the well of the Port Huron Mineral Bath Company. I am informed by Mr. W. L. Jenks, who is now interested in the well, that illuminating gas comes at 400 feet and this mineral water at about 800 feet. Compare, in Geological Survey of Michigan, Vol. V, the water at 772 feet in the Junction well, Pl. LIV. I have included this analysis rather against the wishes of Prof. A. B. Prescott, the analyist, for he does not consider it a natural water. The element which has evidently been tampered with is the bromine, which is so out of harmony with the proportions of other constituents that the discrepancy is apparent at once. Professor Prescott had the Ypsilanti mineral water drawn by his own assistant, and in that water the Br was barely a twentieth part of what it is in this analysis. The potash and iodine may also have been altered in No. 307. But I have thought it best to include the analysis—first, to show how recognizable an altered analysis is likely to be to a student of natural ones. The analysis was recognized as not natural by Professor Prescott and myself quite independently. Again, I think the real mineral water was used as a base, and in some respects the analysis is quite comparable with and an interesting link to the other Dundee limestone water analyses. The sample gave Professor Prescott a specific gravity, at 15.05° C, of 1.070, and the oxides and acids were K_2O 3.537, Na_2O 37.502, MgO 3.116, CaO 4.203, SO_3 2.312, Cl 49.408, Br 5.380, I 0.319, CO_2 0.035, SiO_2 0.010, H_2S 0.649.

It must be recognized that we are dealing with a group of waters which are unquestionably of high healing value and economically of great importance, in which there is lively competition, and where there

s a temptation for an owner to add to his well, before analysis, lements considered desirable, just as the famous Apollinaris water is aid to have a little salt continually added to it. It is legitimate if there s no deception about it and if the water is kept true to its quality. The above statement may apply also to No. 310, though reported to e as coming from a well 340 feet deep. The CO_2 is certainly added, nd the analysis could be nearly reproduced by diluting No. 311 with ure water one-hundred fold. I do not say that this is not an excellent able water. Strong brines must also be diluted to be drinkable, and so he St. Clair mineral water, analyzed by Professor Prescott in December, 894, and the analysis published by the owner, was a dilution of a very trongly saline water, artificially charged with carbon dioxide, and did ot represent a natural water. Most waters are artifically charged for he market.

No. 308 is of water from a well 1,400 feet deep at Benton Harbor (see Geological Survey of Michigan, Vol. V, Part II, Pl. VII). The water is known as Benton Harbor Excelsior mineral water. Prof. John H. ong, of Northwestern University, analyst. The H_2S is cubic inches er gallon at 70° F. Specific gravity of water at 70° F., 1.1058; allowed ar in the reduction.

No. 309 is of water from Coldwater, sent by C. B. Randall. Professor Prescott, analyst, 1893. Compare also Geological Survey of Michigan, Vol. V, Part II, Pl. X. The bases and acids determined were as follows:

Specific gravity, at 20° C., 1.139.

	Parts per Thousand.
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
Chlorine	[illegible]
Bromine	[illegible]
Sulphuric anhydride	[illegible]
Silicic anhydride	[illegible]
Silicon dioxide	[illegible]
Estimated as described in an article by Prescott and Dunn, Journal Analytical Chemistry, 1893	[illegible]

No. 310 is of Salutaris water, bottled and put on the market Analyst, C. F. Chandler. Reduced from grains per United States gallon to grains per liter or kilogram. Chandler's No. 2779, June 1 1890. This water is said to be from a well 340 feet deep, and cased down to rock. Compare above under No. 276; see also Geological Survey of Michigan, Vol. V, Part II, Pl. LXII. It is barely possible that by an unexpected fold or fault the Berea grit comes in here, for the water resembles very much that of Wales (No. 122) and Birmingham (No. 285).

No. 311 is of water from the St. Clair mineral springs. Cited by ale, op. cit., page 149; no analyst is given. The analysis is not com- ete, and I have doubts as to whether it is in grains per United States imperial gallon, and also as to the specific weight.

No. 312 is of water from the St. Clair spring, Oakland House well. pth, 1,250 feet, cased 1,000 feet. Statement published in pamphlet in grains per United States imperial gallon (really imperial gallon). nalyst, S. P. Duffield. "I think you would find more salt if you went per." "Your water shows a large proportion of calcic chloride." is analysis is remarkable for the largest proportional amount of rth chlorides, and yet only traces of bromides, etc. It would be eresting to know how much potash the water contains. (Compare o. 313.)

No. 313 is of Somerville spring mineral water, St. Clair, Michigan. atement in published pamphlet in grains per imperial gallon (as the ures are multiples of 7). Analyst, S. P. Duffield. This well is very ose to that from which sample No. 312 was taken, and yet the waters e markedly different; the analyses were made by the same chemist. o the potash and bromide belong to an upper flow which is cased out No. 312? In other cases also the KCl and the $CaCl_2$ are inversely oportional.

No. 314 is of water from the Mount Clemens original well, which has so at times been known as the Avery and the Soolbad. Analyst, . F. Meier; cited in grains per gallon without specific weight, by Peale, . cit., page 148. This water is the least mineralized of all the Mount lemens waters analyzed, having as much or more NaCl, but being ficient in earthy chlorides, elsewhere so marked a feature of the aters. As the Mount Clemens resort, like most Michigan resorts of is class, started in an abandoned salt industry, this may represent ore nearly the original brine, the casing being afterwards withdrawn let in brine stronger in other constituents.

No. 315 is of water from the same well as No. 314—the Avery. nalyst, S. P. Duffield. As given by Peale this is in grains per United ates gallon, and the $CaSO_4$ is stated as 100.56. In pamphlets I find e $CaSO_4$ 100.335 and the gallon stated as the imperial, the same ures, which are mostly multiples of 7, being used. This is the alysis of Mount Clemens water most often cited in other reports for mparison. The presence of nitrogen is interesting. Perhaps some the rare gases recently discovered which have masqueraded behind are also present.

No. 316 is of water from the same well as Nos. 314 and 315—the olbad. Analyst, S. P. Duffield, 1884. Only a partial analysis. Cited r Peale, Bulletin U. S. Geological Survey No. 32, page 148.

No. 317 is of water from the Clementine well, 1,060 feet deep, at ount Clemens, B. B. Coursin, proprietor. Cf. Geological Survey of ichigan, Vol. V, Part II, Pl. XLII. Fenton Hotel. Analyst, Theo.

Tonnelé, McKeesport, Pennsylvania, June 14, 1893. Specific gravity 1.1313. Given on advertising card as in grains per United States gallon; specific gravity allowed for, the units for gas not given. Total solids by evaporation, at 20.5° C., 10,786.3 grains per gallon. By summation, including S 10,874.526 hydrosulphate and hydrosulphite of sodium lumped together, but not the clay and sulphide of iron, as insoluble matter. The sulphide of iron and free S indicate decomposition of the H_2S and precipitation on the long journey to Pennsylvania.

No. 318 is of water from the Mount Clemens Medea well. Depth 1,244 feet. Second well put down. See Geological Survey of Michigan, Vol. V, Part II, page 71. Analyst, S. P. Duffield, 1884. Cited by Peale, Bulletin U. S. Geological Survey No. 32, page 148, as in grains per United States gallon. This analysis is so similar to No. 319 as to appear like an incomplete version of the same; but the latter is given in grains per imperial gallon.

No. 319 is of water from the same well as No. 318. Analyst, S. P. Duffield, cited from pamphlet in grains per imperial gallon. In NaCl, $MgCl_2$, and in total solids this checks well with the Clementine analysis, No. 317; but No. 319 has $CaCl_2$ where No. 317 has the same amount approximately divided between potassic and calcic chloride.

No. 320 is of the water of the Mount Clemens Sanitarium Company, Limited. This is from the most recent well, 1,000 feet deep, with, it is believed, only 70 feet casing. Analyst, John E. Clark. Water taken July, 1896. Analysis dated August 5, 1896. Gas in cubic inches; other constituents in grains per imperial gallon. I have not been able to find by inquiry whether or not the specific gravity was taken into account, but I have assumed for the reduction that the imperial gallon was taken as 10 pounds. In this sample and in No. 319 CO_2 was present, but was not estimated, and the iron sulphide precipitate is included in the summation.

No. 321 is of water from the well of the Windsor Salt Works, Windsor, Ontario (directly opposite Detroit). Analyst, F. E. Englehart. Specific gravity 1.1817. I have taken this analysis, in default of any analysis of water on the Michigan side of the river, to show the nature of the lower salt brine.

The foregoing analyses show clearly the nature of the waters from a geological point of view. Passing through the impervious cap of black shale, at first comparatively weak water strongly charged with gas, especially H_2S, is struck (analyses Nos. 296, 300, 301, and 303 to 307). Penetrating deeper we come to a set of strata saturated with bitterns or mother liquors (cf. Nos. 283 and 284 with Nos. 318 and 319) deposited from the sea which was left after the great beds of rock salt, which have been and are now actively exploited through still deeper wells (analyses Nos. 320 and 321), had been laid down. Organic matter, as already mentioned, may have decomposed $CaSO_4$ and produced the H_2S.

The records of various wells, as given by Mr. Wright in Vol. V of the

ports of the geological survey of Michigan, contain a mass of data as the specific gravity of the brines at the various depths, illustrative these points.

No. 322 is of water from the Canfield & Wheeler well at Manistee; eological Survey of Michigan, Vol. V, Part II, Pl. XXXI. A. B. rescott, analyst. Analyzed between 1883 and 1890. Specific gravity 60° F., 1.20054.

No. 323 is of water from the same well as No. 322, and by the same alyst; 1893. Evidently the brine had deteriorated in purity. Specific ravity at 16° C., 1.26; at 25° C., 1.255. The analysis was only partial, follows:

Cl	184.477
Br	9.730
CaO	65.352
MgO	24.280
Fe	Tr.
SO_3	Sl. tr.
K	Tr.
Li	Tr.

A provisional estimate of the potassium was obtained (weighing otassic platinic chloride) giving 0.0169 per cent of K_2O. An estimate the lithium weighed as sulphate gave duplicates for 0.0111 LiO_2, ich "is surely far too high."

The estimate of the bromine was made by the indirect method scribed in Journal of Analytical Chemistry, Vol. III, page 375, 1889, ut with a solution of silver nitrate of known strength for precipitaion and estimating the excess of this solution used, so that the conumption of silver nitrate in precipitating can be held as a control for the weight of metallic silver obtained through reduction of a known amount of silver chloride bromide.

No. 324 is of brine from Sand Beach mineral well. Depth, 1,920 feet. See Geological Survey of Michigan, Vol. V, Part II, pages 80–83. R. C. Kedzie, analyst, August, 1890. Original figures are in grains per imperial gallon of 10 pounds. This and the two following analyses have an interesting history. The well whose record is given, loc. cit., was originally a salt well. When Dr. Kedzie's analysis showed the astounding and unsuspected proportions of K and Br given, Mr. George W. Jenks had the sample sent to S. P. Duffield for verification. The analysis returned, No. 325, shows an even stronger water, and, curiously enough, all the constituents increased in exactly the same proportion. Finally, a sample sent in 1896 to Hetherington & Rasher, an English firm of commercial chemists, with a view to testing before exploiting such remarkable richness, gave analysis No. 325, in which the Br and K have dropped to more usual proportions. Some comments may be made later on this whole subject. Suffice it to say now, that a considerable sample of the original water still exists at the Agricultural College, and there is every reason to believe that the

original analysis is a correct one of the original water at 1,860 feet. The sample analyzed in 1896 was mixed with a deeper water, for the well was then deeper.

No. 325 is of brine from Sand Beach. S. P. Duffield, analyst. Reference as above. Specific gravity at 60° F., 1.180. Statement given in grams per liter (really per kilogram). H_2S is 0.2271 gram or 10.745 cubic inches. Total solids directly estimated per liter, 311.6 grams.

No. 326 is of brine from Sand Beach, taken in 1896. Analysts, Hetherington & Rasher, England. Specific gravity, 1.187. Probably in this analysis the imperial gallon is really a volume, and not as in the two previous analyses 10 pounds; in such a case the total solids would agree closely. The reduction is, however, made by dividing by 70.

The next group of analyses are all from the same well—that of the Alma Sanitarium, Dr. J. H. Lancashire, president. The well record is illustrated in fig. 2, which, being of a deep well in the center of the basin, illustrates also the general relations of the strata for most of the other wells mentioned. The Berea grit, however, was not reported in this well; this is quite strange, as the formation is well developed at Bay City. These wells do not give off H_2S perceptibly, but a small amount of illuminating gas is discharged which the analysis does not mention. The effect of pulling back the casing so as to let in the Marshall waters seems to increase the bromine and decrease the total solid constituents. The relative increase of salt and diminution of chlorides of lime and magnesia agree in indicating that thereby a more purely salty brine like No. 281 is admitted. A similar experience was had at Ypsilanti. In other words, the Alma water is a mixture of the upper bitterns of Mount Clemens with a brominiferous Marshall water. The analyses are stated in grains per United States gallon, and I have not been able to obtain the original figures nor the specific gravity, but they should be reduced to parts per thousand, for comparison, by dividing by about 70; this implies a specific gravity of about 1.2, which must be nearly correct.

No. 327 is dated August 17, 1894. Analysts, C. F. Chandler and C. E. Pellew, of Columbia University. See Geological Survey of Michigan, Vol. V, Part II, page 46.

No. 328 is dated May 24, 1894. Same analysts and references as No. 327. The casing had been pulled back for the above analyses, I am informed.

No. 329 is dated January 15, 1890. The well struck this water in March, 1889. This I understand to be purely the bottom water. Another account of the casing is as follows:

This well was cased with 8-inch casing 500 feet, then a 5⅝-inch casing 615 feet. At 1,053 feet the hole was reduced to admit a 4½-inch casing, which was eventually carried down to the 1,500-foot level. From this point there is no casing and we are using a pump that extends down 1,500 feet.

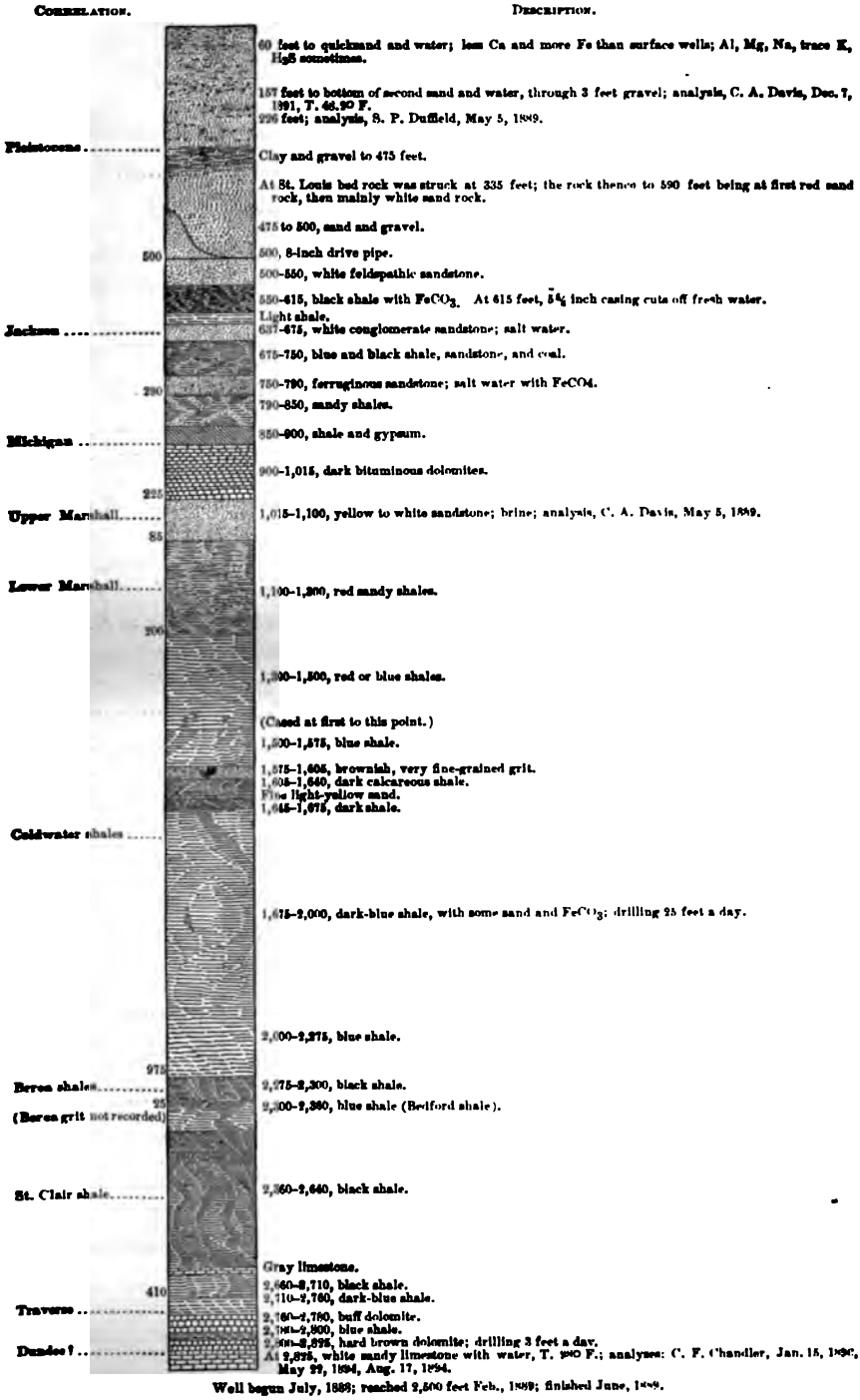


FIG. 2.—Geological column at the Alma Sanitarium.

Constituent.	306. Ypsilanti (Atlantis well).	307. Port Huron.	308. Benton Harbor (Excelsior well).	309. Coldwater.	310. St. Clair (Salutaris water).	311. St. Clair mineral spring.	312. St. Clair spring.
Al_2O_3			*0.035* .005	*a* 0.643			*849.00* 12.00
$CaCO_3$	0.827		Tr.			*0.15*	Tr.
$CaCl_2$	3.000	5.118	*1,378.24* 21.350	*1,535.786* 22.717	*b 5.1337* bi. .0879	*2,457.49*	*7,362.2* 105.40
$CaSO_4$	.666	3.930	*85.449* 1.324	*13.901* .205		*140.19*	*144.2* 2.06
$FeCl_2OH$				*11.279* .167			
$FeCl_3$				*3.672* .054			
LiCl	*d* Tr.		Tr.				
Barium	Tr.						
$MgCO_3$					*c 3.8814* bi. .0665	*1.10*	Tr.
$MgCl_2$	1.911	1.012	*605.90* 9.386	*791.42* 11.70		*398.38*	*1,012.7* 144.6
$MgBr_2$	.193	12.374	*46.72* .725	*101.193* 1.497		Tr.	
$MgSO_4$	1.320						
Fluorides	Tr.						
Phosphates	Tr.						
KCl		5.511	Tr.		*1.6979* .0293		
K_2SO_4	.527	.080			Tr.		
Silicates	.015						
SiO_2		.010	.233 .004	*d* .0109	.5717 .0098	*29.41*	*96.90* 5.00
NaCl	34.457	70.871	*6,821.12* 105.680	*10,911.25* 161.39	*81.8344* 1.388	*e 56.501*	*8.20* 116.00
NaI		.377				MgI tr.	MgI tr
NaS				.1346 .002			
$NaHCO_3$					*4.8754* bi. .08135		
Organic matter	Tr.				Tr. NH_3		
Total by addition	42.916	99.283	8,938.002			*12.57173*	17,904.6
Total by evaporation			138.474	*13,412.831* 198.3601	*97.4943* 1.671		255.78
H_2S	*f* 15.527	.649	*f* 27.8	Tr.		*f* 16.43	*f* 25.58
CO_2					*465.325*		
Sp. wt			1.1058				

a Aluminum sulphates.
b $CaH_2(CO_3)_2$.
c $MgH_2(CO_3)_2$.
d And borates.
e + KCl.
f Cubic inches.

Constituent.	312. St. Clair (Somerville spring).	314. Mount Clemens (original well).	315. Mount Clemens (Avery).	316. Mount Clemens (Soolbad).	317. Mount Clemens (Clementine).	318. Mount Clemens (Media).	319. Mount Clemens (Media).
Al_2O_3			29.47 .421	11.21	2.920 .044	29.00	42.07 .601
NH_4Cl		Tr.		Tr.		Tr.	
$CaCO_3$		3.98	0.98 .014	Tr.		91.00	0.91 .013
$CaCl_2$	2,803.78 40.054	172.41	934.5 13.35		2,837.606 42.830		4,128.53 58.979
$CaSO_4$	87.78 1.254	35.20	100.335 1.433	44.00	69.970 11.060	14.30	142.43 2.049
Fe_2O_3	30.100 .430			Tr.		8.500	
$FeCO_3$			.560 .080				8.54 .122
$FeH_2(CO_3)_2$					1.924 .029		
$FeCl_2$							
FeS		Tr.			a453.536 6.5626		
LiCl				Tr.			
$MgCO_3$		Tr.	0.70 .01	Tr.		0.70	0.07 .001
$MgCl_2$	242.20 3.470	129.60	642.43 9.264		1,223.008 18.806		1,656.2 23.66
$MgBr_2$	66.20 .980		6.57 .091	Tr.		Br. 3.50	8.54 .122
MgI_2		b 0.32	0.07 .001	b 0.05		b .07	.07 .001
KCl	1,680.00 24.00	Tr.		Tr.	1,057.889 116.020		
SiO_2	119.00 1.700	c 3.97	27.60 .394			28.00	28.09 .401
NaCl	8,983.94 128.342	8,637.44	11,900.00 170.00	d 11,181.00	5,684.255 86.080	11,741.00 (e)	5,967.35 85.105
Na_2SO_4	f 11.9 .170	77.25			g 1.960 .0		
Sr					Tr.		
S					Tr.		
Organic		Tr.					
Total solids	14,028.00 200.4	9,065.17 155.00	13,654.105 195.062	11,236.26 192.00	10,874.526 164.678	11,921.07 170.301	11,973.80 171.054
H_2S		h 27.52	h 40.00	h 33.00	h 9.910	h 40.00	h 38.00
CO_2		Tr.	h 5.85		h 3.457		

a Insoluble and not included in summation.
b Iodine.
c $+Al_2O_3$.
d $+Ca+Mg$.
e $Na+Ca+Mg$.
f Hydrous.
g Hydrosulphate and hydrosulphite of sodium.
h Cubic inches.

Constituents.	320. Mineral Springs Sanitarium.	321. Windsor, Ontario.	322. Manistee No. 1.	323. Manistee No. 2.	324. Sand Beach No. 1.	325. Sand Beach No. 2.	326. Sand Beach No. 3.
$CaCl_2$	[illegible] / 245.759	.3649	$CaMg\ Cl_2$ / 2.449	139.54	56.89	62.0636	2,835.00 / 41.07
$CaSO_4$	75.[illegible] / 1.0[illegible]	5.441	4.265	.....	.30	.9936	49.1 / .31
$FeCl_2$, $(CO_2)_2$	5.[illegible] / .[illegible]	.....	.....	.....	.....	.....	.....
$BaCl_2$	2[illegible] / e 1.757	.....	.....	.....	Tr.	.....	.....
LiCl	.....	.....	.....	Li_2O .111 f	.....	.....	.....
Na_2Cl_2	[illegible] / 22.[illegible]	1.0[illegible]	.....	48.11	4.85	5.3542	1,371.00 / 22.44
$Na_2B_4O_7$	Tr.	.....	.....	11.19	22.500	24.84	58.1 / .[illegible]
$Na_2S_2O_3$	Tr.	.....	.....	.....	.....	.....	.....
KCl	2.[illegible] / .[illegible]	.....	.....	.....	34.22	37.7788	115.00 / 2.07
K_2O	.....	.....	.....	.109 f	.....	.....	.....
SiO_2	2.119 / .030	.....	.....	.....	.....	.7303	.....
NaCl	8,[illegible] / 124.4187	227.4187	(b)	111.14	164.64	179.2391	14,530.00 / 239.29
Loss	.....	.....	.....	.....	.....	.....	1,079.00 / 15.434
Total solids	29,347.577	.....	.....	.....	29.740	21.872	20,021
Grams per liter	284.9611	234.4872	262.00	297.98	282.00	311.60	288.13
H_2S	e 18.00	.....	.....	.....	e 10.5	e 10.745	.....

a Fe. b Most [illegible] NaCl. c In cubic inches.

Constituents.	327. Alma No. 1.	328. Alma No. 2.	329. Alma No. 3.	Constituents.	327. Alma No. 1.	328. Alma No. 2.	329. Alma No. 3.
Al_2O_3	[illegible]	[illegible]	[illegible]	SiO_2	[illegible]	[illegible]	[illegible]
NH_4Cl	[illegible]	[illegible]	.....	NaCl	[illegible]	[illegible]	[illegible]
$CaCl_2$	[illegible]	[illegible]	[illegible]	$NaBr$	[illegible]	[illegible]	[illegible]
$FeCl_2$	[illegible]	[illegible]	[illegible]	NaI	Tr.	Tr.	Tr.
LiCl	Tr.	Tr.	Tr.	Sodium phosphate	Tr.	Tr.	Tr.
$MgCl_2$	[illegible]	[illegible]	[illegible]	Total	[illegible]	[illegible]	[illegible]
KCl	[illegible]	[illegible]	[illegible]				
K_2SO_4	[illegible]	[illegible]	[illegible]				

RÉSUMÉ.

In spite of the difficulties, upon which I have enlarged perhaps too ch, I am able to make some generalizations of interest and I trust practical value.

If we take any one stratum yielding water, we find that the deeper is the more strongly mineralized it is. At the margin the salts are re often carbonates and sulphates, and are replaced below by chlo-les, and the earthy chlorides and bromides, etc., appear to be richer the deeper or central parts. But the rate of mineralization is far m the same in different beds. The freshest horizons for a given pth appear to be the Dundee and the Marshall. The former appears be characteristically sulphureted, far more so than any other hori-n. The latter is the chief horizon for potable water, and is capable supplying a large part of the State, but must be shielded in many ses from overlying waters. Above the Marshall the waters are likely be mineralized even if quite shallow, and generally strong in sul-ates, with or without salt. Below the Marshall is the Berea grit, hich is somewhat saline even in shallow wells, yields excellent brine the deeper wells, illuminating gas and oil rather than H_2S, and is rked by the predominance of sodium and the relative freedom from rthy chlorides. Has this any connection with its isolation in a shale ries away from any limestone? Below the Dundee the predominance these earthy chlorides is characteristic, and also probably the con-ntration of K and some of the rarer elements from the great salt positing process, the results of which we find still farther down.

So far as the rarer elements and less sought for compounds are con-rned, it must be said, however, that analytical methods are not yet tisfactory for brines. The Midland Chemical Company is a large nufacturer of bromine, practically dominating the industry, and is id to have improved methods of analysis. But these are commercial nsiderations. I have had complaints that efforts had been made in in to get from the East Tawas brines the bromine that was said to there. Again, the presence of celestite associated with sulphur at ofield and other points in the Helderberg series, suggest that Sr must a constant constituent of the sulphureted waters. But its presence, en in traces, is rarely noted in the analyses. Doubtless, if especially oked for, it would be found more widely diffused. On the other hand, have been assured by a competent chemist that the Michigan brines ffer from those of Ohio and Pennsylvania in the absence of iodine d lithium. Ammonic chloride, reported from Alma, is probably idespread and generally overlooked.

From the Dundee and the limestone series below are a number of teresting brines which we are not yet able to differentiate. The first alysis of the Sand Beach brine was, I believe, correct, and the bro-niferous pocket was either exhausted or diluted with a lower water,

for even the English analysis shows a notable amount of K and Br. The general criticism may be made, on the exploitation of the undoubtedly valuable medicinal bitterns of Michigan, that too little attention and study has been given to the precise effects of the various components in particular classes of diseases. Although both a sulphureted water and a saline water have medicinal values, they are not exactly the same. Yet the usual custom is to let them flow together and to continue boring until the salinometer shows considerable strength, so that "the bathers may feel the buoyancy and feel that they are getting their money's worth," and it is desired that the analysis may show as strong a water as a neighboring establishment, or a similarity to some famous water. No attempt to separate the various waters and use them according to the circumstances of the case seems to have been made, further than to have one well for drinking and another for bathing. And yet anywhere along the Detroit and St. Clair rivers it would be easy enough to have, even from one well, a sulphureted water, a calcium chloride water, and a strong salt water, and perhaps other varieties, to be used as each case required.

I have been told that hygienic living and drinking plenty of water are essentially the most important curative agents, and next to them is salt. So far, however, as particular mineral and gaseous ingredients are really of importance, the plan above suggested would certainly be a step in advance. Again, in view of the evidence of gradual changes in analysis, perhaps from deterioriation of casing, it would be well to keep weekly records of salinometer strength and temperature and also of the quantity of water pumped, which would quickly indicate any leak in the casing, and if any notable difference was thus detected it might be well to analyze the water again.

In studying the sanitary analyses of potable waters I am brought to the conclusion that, so far as typhoid and kindred diseases are concerned, direct microscopic investigation and bacteriological study are more important than consideration of chemical constituents as indicators of sewage contamination. It is easy to see that chlorine in particular is no guide, unless one knows accurately the normal percentage for uncontaminated water under the same geological conditions. Prof. Delos Fall, of the State board of health, is pursuing researches along this line. In many cases even an abnormally low percentage of mineral matter or salt is suspicious, as indicating dilution with rain and other surface water. This is especially true of abnormally soft waters.

I have given the dates of the analyses, because the State board of health has shown that the prevalence of typhoid fever increases with the lowering of the water in the wells, the curves of their diagram showing the prevalence of typhoid from month to month and the parallel lines the height of water in the wells. The lowest water (231 inches below ground on the average) and the greatest number of cases of typhoid occur in October, the highest water (197 inches below ground) and the fewest cases of typhoid in the spring.

MAP SHOWING AREAS OF HEAVILY MINERALIZED SHALLOW WATERS.

Not only does ammonia occur in peaty waters, which are not necessarily dangerous, though likely to be malarial, but in the Alma well, at a depth of 2,860 feet we find it playing the same rôle as magnesium or calcium. Hence it is not a reliable indication of contamination. It does not, however, by any means follow that a chemical examination of ordinary waters is valueless. With due regard to all conditions, such analyses may furnish valuable indication as to sewage contamination, and it is one of the objects of this paper to enable the chemist to study and judge what the normal analysis should be. But germ diseases are not the only ailments of man, and extremely hard waters, like those around Mount Pleasant, are by no means wholesome simply because there is no possible surface contamination. The relation between the percentage of various mineral constituents and certain chronic diseases, and the uric acid diathesis has not, to my knowledge, been carefully studied. The map (Pl. IV) shows by shaded areas those parts of the State where the waters commonly drunk are most likely to be highly charged with mineral matter, and it would be interesting to see if these areas correspond in any significant way to disease distribution. Of course in these shaded areas there are many surface wells of nonmineral waters. Yet the waters of many wells are strongly cathartic or otherwise unpleasant to those unused to them, as strangers coming temporarily to help in harvest and threshing soon discover. It seems natural to suppose that a water which will favorably affect some sick people will unfavorably affect others, and that some waters may be permanently too strong for some constitutions, while other systems which may be at first decidedly unsettled by them in time become perfectly accustomed to them. Throughout the central or shaded area, in chronic diseases like rheumatism and constipation it might be worth while to experiment with pure filtered rain water (flavored if necessary with a little salt or lithium carbonate) as a beverage.

In regard to brine for salt making, rock salt and very pure brines occur in the Salina, north of a line from Trenton to Muskegon. Next ranks the brine of the Berea, and then that of the Marshall.

Just above the Salina the rocks seem to be saturated with bitterns. That would seem to be a most hopeful field to develop for potash salts. September 29, 1899, newspapers report that explorations, particularly for potash, will begin in October. Some of the Coal-Measure waters seem also to run relatively high in potash. At considerable depths both this horizon and the Marshall seem to possess bromides in valuable quantities.

APPENDIX.

The Appendix contains some analyses which were received too late for insertion in their proper places without entirely renumbering the analyses. References to these later analyses have, however, been

inserted in the proper place in the body of the text, and the place in which each should come is indicated by the number given it.

The first fourteen are cited from the Report of the Special Water Supply Committee of the City Council of Traverse City—the report of Engineers H. F. Northrop and George W. Rafter.

No. 2A, of water from the west arm of Grand Traverse Bay, was made November 24, 1884. Analyst, R. C. Kedzie. (Op. cit., p. 10.)

No. 2B was of water from the same arm, collected April 18, 1897, from the surface at a point a little north of Carter's dock and about 1,200 to 1,500 feet out from the west shore. Analyst, R. C. Kedzie. (Op. cit., table No. 2.) Some blackening on heating; nitrites none, nitrates a trace.

No. 2C, of water from the east arm of Grand Traverse Bay, was made in April, 1897. Analyst, R. C. Kedzie. (Op. cit., table No. 2.)

No. 2D is of Lake Michigan water at Chicago. (Op. cit., p. 20.)

No. 5A is of Detroit city water. April, 1896. (Op. cit., p. 14.) Microscope shows fine sand, mud, diatoms, and algæ. Oxygen absorbed in fifteen minutes, 0.0003; in four hours, 0.0006. Turbid; reaction neutral.

No. 6A is of Detroit city water. July, 1896. (Op. cit., p. 14.) Oxygen absorbed, 0.00034 and 0.00062, respectively.

No. 7A is of Detroit city water. February 15 to 22, 1897. (Op. cit., pp. 14, 15.) No nitrites. Oxygen absorbed in fifteen minutes, 0.00036; in four hours, 0.00070.

No. 7B is of Lake Michigan water, 5 miles off shore at Milwaukee and 44 feet beneath the surface, where the lake is 118 feet deep. (Op. cit., pp. 18 and 19, where a number of other analyses are also given.) Nitrites none.

No. 7C is of Lake Michigan water, near Chicago, 12 miles out. October 23, 1896, on which date the city water contained 0.0031 NaCl. (Op. cit., p. 19, where other analyses are also given.) No nitrites or nitrates.

No. 35A is of water from Boardman River, which empties into Grand Traverse Bay at Traverse City. April 19, 1897. Analyst, R. C. Kedzie. (Op. cit., table No. 2.)

No. 35B is a boiler-water analysis of Boardman River water. March, 1896. Analyst, the Dearborn Drug and Chemical Works, of Chicago. (Op. cit., p. 29.)

No. 35C is of water from a brook on the insane asylum grounds, Traverse City. November, 1881. Analyst, R. C. Kedzie. (Op. cit., p. 48.)

No. 35D is of water from a large spring on the land of Hannah, Lay & Co., to the south of the asylum at Traverse City. Analyst, R. C. Kedzie. (Op. cit., p. 49; also report of commissioners appointed to select a location and site for the Northern Michigan Asylum for the Insane, September 30, 1882.) In analyses Nos. 35C and 35D some misprints have been corrected. Both samples were free from odor, faintly alkaline, and contained a small amount of suspended sand and humus.

No. 36A is of water from a brook near the Agricultural College; average of the results of ten students.

Nos. 43A, 43B, 43C, and 43D are all analyses, made by Messrs. H. and W. Heim for S. G. Higgins, of Saginaw River water. Sample No. 43A was taken opposite the mouth of the Tittabawassee; No. 43B, in front of the East Side waterworks, i. e., about a quarter of a mile downstream; No. 43C, at the Mackinaw street bridge, about a mile and a half farther north and a little below the West Side waterworks; No. 43D, at the Genesee avenue bridge, about 2 miles farther northwest. The organic residue was determined as the difference between the total and the inorganic residues. Neither was determined by summation of constituents.

No. 58A is of the water of the Pagoda Springs, Mount Clemens. Analyst, C. Gilbert Wheeler. Temperature, 52° F.

No. 172A. September 30, 1897. From Lansing waterworks pumping station. Light straw color. No sulphates. Can not produce disease. Chemically somewhat better than 172B. Analyst, Prof. V. C. Vaughan.

No. 172B. September 30, 1897. From the Lansing waterworks, remote from pumping station (No. 216 West Main street). Opalescent. Microscope magnifying 100 and 500 diameters shows a small amount of organic matter; bacteria developed are nontoxicogenic. Analyst, Prof. V. C. Vaughan.

These two analyses were made on account of a typhoid-fever scare, but it was discovered that although city water had been introduced into the house where the disease existed, it had been cut off and well water had been used.

Constituent.	2A. Grand Traverse Bay.	2B. Grand Traverse Bay.	2C. Grand Traverse Bay.	2D. Lake Michigan, Chicago.
Al_2O_3	.....	.....	.....	Tr.
$CaCO_3$	0.0930	CaO. 0.0392	CaO. 0.0393	0.0601
$CaSO_4$	.....	0.	.....	.0273
Fe_2O_3	.....	Tr.	Tr.	Tr.
$FeCO_3$	.003	.....	.....	.....
$MgCO_3$	.0086	MgO. .0146	MgO. .0145	.0200
SiO_2	.007	.....	.....	.006
NaCl	.....	.0064	.0071	(NaK).0177
Na_2CO_3	.....	.....	.....	(NaK).0027
Organic	.0170	Loss. .0600	.0470	.....
Total residue	.1286	.1500	.1100	Mineral, .1338
Total hardness	.....	8.°	8.°	.....
Permanent hardness	.....	5.°	5.°	.....
Free ammonia	.....	.00001	.00002	1.00002
Albuminoid ammonia	.....	.00001	.00002	1.00008
Oxygen from permanganate	.....	.0005	.0005	1.00167

Constituent.	58A. "Pagoda," Mount Clemens.	Constituent.	58A. "Pagoda," Mount Clemens.
Al_2O_3	Tr.	NaCl	*1.959* .0280
$CaCO_3$	*10.273* .1468	Na_2SO_4	*1.234* .0176
$CaSO_4$	*.359* .0051	P_2O_5	Sl. tr.
$FeCO_3$	*.067* .0009	Organic	Sl. tr.
$MgCO_3$	*5.473* .0782	Sum	*20.195* .2885
K_2SO_4	*.306* .0044	CO_2	19.2 cu.in.
SiO_2	*.524* .0075		

	172A. Lansing.	172B. Lansing.		172A. Lansing.	172B. Lansing.
Result of inoculation			Potassium permanganate reduced	0.002	0.004
Number of bacteria in 72 hours		235	Cl as NaCl	.00825	.01485
Nitrites	0	0	Organic residue	.017	.100
Nitrates	0	0	Inorganic residue	.041	.232
Albuminoid ammonia	0.000021	0.000019	Total residue	.058	.332
Free ammonia	.000013	.000021	Hardness	4.°	4.8°

Constituent.	No. 286A. Ypsilanti.	No. 291A. Bay City.	Constituent.	No. 286A. Ypsilanti.	No. 291A. Bay City.
Al_2O_3	*10.5* .15		NaCl	*9,632.99* 137.61	
$CaCO_3$	*194.71* 2.78	.18	NaBr	*12.60* .18	162.86 *b* .17
$CaCl_2$		87.85	NaI	*5.60* .08	
$CaSO_4$	*161.84* 2.312	.04	H_2S	*144.10* 2.06	
Fe_2O_3	*a 17.50* .25	.31	P_2O_5	Tr.	
$MgCl_2$	*255.76* 3.65	10.67	Total solids by evaporation	*10,476.60* 149.67	262.1
KCl	*42.70* .61		Total solids by calculation	*10,478.30* 149.69	262.08
SiO_2					

a Carbonate. *b* MgBr.

No. 286A is a recent analysis of water from the Ypsilanti Sanitarium. Analyst, Prof. John E. Clark, of Detroit. Specific gravity, 1.038; reaction slightly alkaline; analysis in grains per imperial gallon. Note that the H_2S appears to be included in the total solids by calculation.

No. 291A is of the brine encountered in the Bay City deep well at 2,200 feet, which rose to the surface, notwithstanding a specific gravity of 1.2223. Analyst, Prof. F. S. Kedzie.

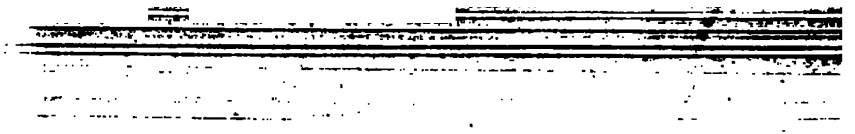
INDEX.

Page.

ologic horizon of water at 45
it..... 40, 52, 54, 56
al College, water at..... 58, 59, 91, 92
arium, geological column at 83
it..... 13, 82, 86
ring at 33, 35
ologic horizon of water at..... 45
it..... 21, 22, 37, 72, 73, 74
r, geologic horizon of springs 37
it 27, 28, 31, 33, 34, 35, 52, 54, 70
ater, analysis of..... 65
er, analyses of 79, 85
n, analyses by 68, 69
..... 68
line well at..... 66, 67
ater at..... 63, 64
k, water at..... 27, 29, 40, 54
aline waters at..... 67, 68
it 19, 20, 21, 27, 28, 41, 43, 48, 56, 61, 93
ater at 58, 59, 63, 64
waters at..... 72, 73
ater at..... 40
rbor. waters at 32, 35, 78, 84
waters from..... 70–71
, waters at 13, 67, 68
m, water at..... 70
River, water of..... 27, 90, 92
aters containing 13–14, 67
idstone, brines of 67
th's magnetic spring, geologic of..... 37
ater at..... 29
gic horizon of water at..... 44
at..... 42
R. C., cited..... 59
, water of..... 27, 28
C. F., analysis by 78
C. F., and Pellew, C. E , analyses 82
., waters at..... 72, 73
d, water at 57
r., analyses by 62, 67
River, water of..... 27, 28
, water of 29
., analyses by..... 34, 64, 71, 93
N., analyses by..... 29
water at..... 39, 78, 84
Dwn spring, Benton Harbor, wa- 32, 35
., analyses by..... 35, 69

Page.

De Boe, John, analyses by..... 34
Devonian or Silurian limestones, waters from 72–86
Detroit, waters at..... 21, 73, 74, 90, 91
Detroit River, waters of..... 18, 19
Dimondale, water at..... 40
Douglass, S. H., analysis by..... 19, 35, 36, 67
Dowagiac, water at..... 39, 53
Duffield, S. P., acknowledgments to..... 12
analyses by.. 36, 60, 61, 62, 65, 73, 74, 79, 80, 81, 82
Eastlake, water at..... 48, 49
East Saginaw, saline wells at 66, 67, 68
water at..... 61
East Tawas, water at..... 48, 70
Eaton Rapids, waters at 60, 61
Edgar and Mariner, acknowledgments to .. 12
Edwards, W. F., analysis by 74
Englehart, F. E., analysis by 80
Erie, geologic horizon of springs near 37
Fall, D., analysis by 35
Fischer, R., and Prescott, A. B., analyses by. 35
Fisk, L. R., analyses by 65
Flint's magnetic springs, source of..... 37
Flushing, geologic horizon of water at..... 44
water at..... 41, 44
Frankfort, waters at 72, 73
Frost, water at 41
Fruitport, geologic horizon of water in well at 37
water at..... 65, 66
Gallon used, discussion of..... 14–15, 16
Garrigues, S. S., cited 62, 69
Gladwin, water at..... 55
Goessmann, C. A., analyses by..... 62, 66
Grand Haven, geologic horizon of spring at 37
water at..... 39, 65, 66
Great Lakes, waters of..... 18–26
Grand Ledge, geologic horizon of water at 37
Grand Rapids, geologic horizon of magnetic spring at 37
water at.. 31, 34, 39, 48, 49, 50, 51, 52, 53, 54, 65, 66
Grand River, water of..... 27, 28
Grand Traverse Bay, water at..... 90, 91
Grasmere, water at..... 63, 64
Graves, J. E., analyses by 28, 36, 62
Greenville, water at..... 31, 34
Hahn, H. C., analysis by..... 67
Harbor Springs, well at 31, 34
Hastings, water at..... 48
Heath, G. L., acknowledgments to..... 12
analyses by 70



J C Branner

DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

RIGATION PAPERS

OF THE

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UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

ER RESOURCES OF PUERTO RICO

BY

HERBERT M. WILSON

WASHINGTON
GOVERNMENT PRINTING OFFICE
1899

CONTENTS.

	Page.
nsmittal	9
relief	11
topography	14
raphy and scenery	15
	21
ation	22
ature	24
y	24
on	28
l lands and soil	32
ls and fertilizers	33
tural products	34
	41
r and supply	43
ion facilities	44
	47

ILLUSTRATIONS.

Page.

TE I. Drainage and hypsometric map of Puerto Rico 11

II. *A*, Carolina Plain with El Yunque in distance; *B*, Playa at mouth of Rio Loiza; *C*, Rio Canovanas; *D*, Foothills of Sierra de Luquilla, showing field and cocoanut trees 16

III. *A*, West from Cayey divide; *B*, Rio Jacaguas near Juana Diaz .. 16

IV. *A*, Between Cayey and Aibonito summit; *B*, Caguas Valley and El Monte; *C*, Hills along Rio Añasco; *D*, Near summit of Adjuntas Pass 18

V. *A*, Scenery south of Aibonito summit; *B*, Bent mango trees, San Juan 18

VI. Barren hills near Juana Diaz 20

VII. *A*, Westward toward Lares from La Torre summit; *B*, Toward Lares from the east; cocoanuts and bananas in foreground. ... 22

VIII. *A*, Parting Valley about and hills back of Yauco; *B*, Arid flora near Lares; *C*, Fording Rio Loiza, near Carolina; *D*, Rio Portugues, at Ponce 26

IX. *A*, Rio Descalabrado; *B*, Rio Añasco; *C*, Regulator gate and ditch; *D*, Wing dam 28

X. *A*, River bed and masonry conduit; *B*, Irrigation ditch in earth; *C*, Sugar land near Ponce; *D*, Guinea grass, Caguas Valley 32

XI. *A*, Mountain summits under cultivation; *B*, Ox cart; *C*, Saddle and pack horse; *D*, Hogs led by rope 34

XII. *A*, Sugar cane; *B*, Train of cars loaded with sugar cane drawn by oxen; *C*, Coffee shade; *D*, Shelling coffee 36

XIII. Map showing distribution of crops 38

XIV. *A*, Cotton plant; *B*, Market scene, Ponce; *C*, Logs of ausubo en route to market; *D*, Repairing military road 40

XV. *A*, Mamey (bread fruit) tree in field of yautia, Rio Canovanas; *B*, Clump of bamboo; *C*, Near summit of Sierra de Luquilla; *D*, Ceiba tree in field of guinea grass 42

XVI. *A*, Muddy cart road near Adjuntas; *B*, Muddy cart road near Aibonito; *C*, Rocky cart road near Lares; *D*, Rutted coral rock in cart road near San Sebastian 44

XVII. *A*, Bridge over Rio Cana near Caguas; *B*, Rocky cart road near Lares 46

IG. 1. Section north and south through El Yunque 12

2. Section north and south through San Juan 13

3. Section north and south through Ponce 13

4. Cordillera Central, parting valley, coast limestone hills, and playa at Ponce 15

5. Piloncillos, or conical coral hills; Lares 20

6. Inverted siphon carrying ditch under military road 30

7. Masonry conduit and retaining wall 31

8. Cultivated hilltops in Cayey tobacco district 37

9. Drying coffee on rolling platforms; Pietris plantation, Adjuntas ... 38

10. Rockwork near Aibonito, summit of military road 45

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, July 31, 1899.

SIR: I have the honor to transmit herewith a manuscript relating o the water resources of Puerto Rico and to request that it be pub-ished as one of the series of Water-Supply and Irrigation Papers. The report is based on notes, sketches, and photographs gathered by Mr. Herbert M. Wilson during a brief journey made through the island of Puerto Rico in January, 1899. The object of this trip was primarily to study the topographic characteristics and the water resources of the island, but incidentally numerous memoranda rela-ive to the soil, agricultural products, and forests were obtained.

Mr. Wilson landed at the capital city of San Juan, whence a short rip was made by rail via Rio Piedras to Carolina, whence saddle nimals were taken still farther eastward to Canovanas and south-ward up the river of that name to its head waters, in the Sierra de uquilla. After returning to San Juan he proceeded by ambulance ver the military road, which crosses the island diagonally toward the outhwest, via Caguas, Cayey, Aibonito, Coamo, and Juana Diaz, to once, traveling by slow stages and making the distance of 80 miles n four days.

At Ponce Mr. Wilson and his party were furnished with pack and addle animals and civilian packers and set out the next day via djuntas and Lares, San Sebastian, and Añasco to Mayaguez, on the est coast. Thence the return journey to Ponce was made on horse-ack via Hormigueros and San German to Yauco, where rail was aken for Ponce.

Thus the trip included the country from the mountain tops near the astern end of the island to near the southeast coast above Guayama nd to the south coast at Ponce, a return to near the northwest coast t Lares, and a circuit of the southwestern coast from Mayaguez to once. The party crossed or visited the head waters of all the more mportant streams, saw nearly the entire country from the vantage oints of the high summits, and visited nearly all of the larger cities xcept those at the eastern extremity of the island.

This route led into the highest mountains at the eastern end of the island, within view of El Yunque, the highest peak; also into the Sierra de Cayey and the Cordillera Central, occupying the main length of the island, and, finally, into the low coral sugar loaves near Lares, and the limestone and volcanic foothills of the Tetas de Cerro Gordo and Las Sillas de Calderon, in the southwestern corner of the island. The data thus obtained concerning the water resources of this newly acquired portion of the United States are believed to be of sufficient importance to warrant early publication in this series of papers.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

WATER RESOURCES OF PUERTO RICO.

By HERBERT M. WILSON.

TOPOGRAPHIC RELIEF.

Puerto Rico, as shown on the map (Pl. I), is situated between latitudes 17° 54′ and 18° 30′ north and longitudes 65° 13′ and 67° 15′ west, thus lying well within the Torrid Zone. It is the easternmost as well as the southernmost of the Greater Antilles, though still farther to the east are the lesser of the West Indian islands belonging to the Windward Group. The shores are washed on the north by the waters of the Atlantic Ocean, on the south and east by those of the Caribbean Sea, and on the west by Mona Passage, which separates the island from Haiti. According to the best information obtainable from measurement of existing maps, the area of Puerto Rico, exclusive of the dependent islands—chief among which are Mona on the west and Viequas and Culebra on the east—is 3,670 square miles. Its area is thus one-fourth, or 1,200 miles, less than that of the State of Connecticut, and is nearly three times as great as the area of Long Island. Its average width is 35 miles, or twice the width of Long Island, while its average length is 105 miles, or about the same as that of Long Island. Fourth of the Greater Antilles in size, it is roughly rectangular in form, its major axis lying almost exactly east and west.

The essential topographic characteristic of Puerto Rico is its exceedingly mountainous and highly eroded aspect, in spite of which none of its summits attain great altitude. The island is also notable for the abruptness with which the foothills of the mountain slopes plunge into the ocean, leaving practically no marginal coast plain, and for the variety in topographic form, resulting from great differences of erosive action at either extremity of the island and from changes in geologic structure. Extending irregularly through the entire length of the island from the extreme northeastern point, at Cabeza de San Juan, to the extreme western points, near Rincon and Cabo Rojo, is a series of connected mountain ranges forming the main divide between the drainage of the north and south coasts. At the eastern end of

this island the most commanding range, the Sierra de Luquilla, minates near its eastern extremity in the highest peak on the isl El Yunque, the elevation of which is given by Spanish authoriti 1,520 meters, or approximately 4,940 feet. This appears to b error, since, according to an aneroid reading by Mr. A. Hansar height is about 3,250 feet, while the maps of the United States Department and charts of the United States Hydrographic Office of the United States Coast and Geodetic Survey give its altitu between 3,610 and 3,790 feet. Which of these elevations is nearly correct it is at present difficult to ascertain. A north-south

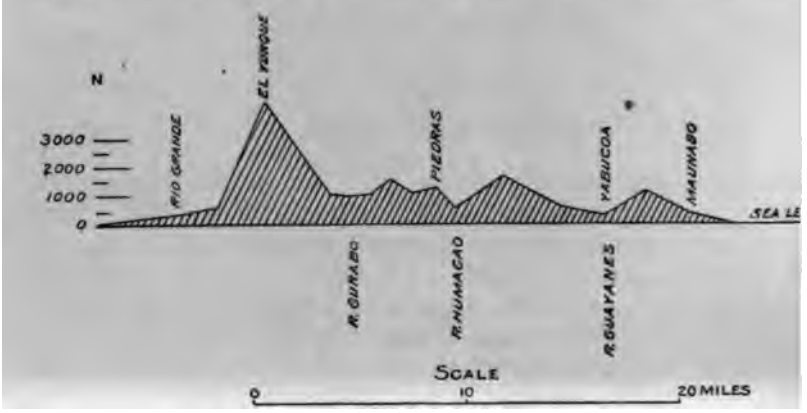


Fig. 1.—Section north and south through El Yunque.

section through El Yunque (fig. 1) gives some idea of the abru of the fall to the north, and is in striking contrast to the cross se taken elsewhere on the island (figs. 2 and 3), which show the st slopes to the south.

A southern spur of the Luquillas connects this mountain rang the northeastern spur of the Sierra de Cayey in a low divide miles from the coast, near Humacao; thence the Sierra de extends westward to Aibonito Pass with comparatively uniform tions between 2,200 feet in the lowest divides and 3,200 feet highest summits, none of which are especially pronounced. Th tion of the main range of mountains skirts the eastern and so coasts very closely, so that the greater portion of the drainage eastern third of the island is to the north, the southern and e coasts receiving the drainage from a narrow belt of country b 10 miles in width. The length of the drainage to the north, me in an air line, is from 25 to 30 miles.

At Aibonito the military road from San Juan to Ponce passes tl the lowest divide in the central range of mountains, the eleva this being approximately 1,840 feet above sea level. As a re the closeness with which these mountains skirt the eastern and ern coasts, they suddenly fall off in a distance of but 2 to 3 mile

tally from altitudes of 2,500 to 3,000 feet to the back coast border, elevations of 200 to 300 feet. The abruptness of the escarpment to south and east can thus be realized, and is illustrated by a north-th cross section (fig. 2) constructed through Guayama and San an. This cross section also shows that the fall to the north, while so great, is still quite abrupt, reaching the elevated basin about

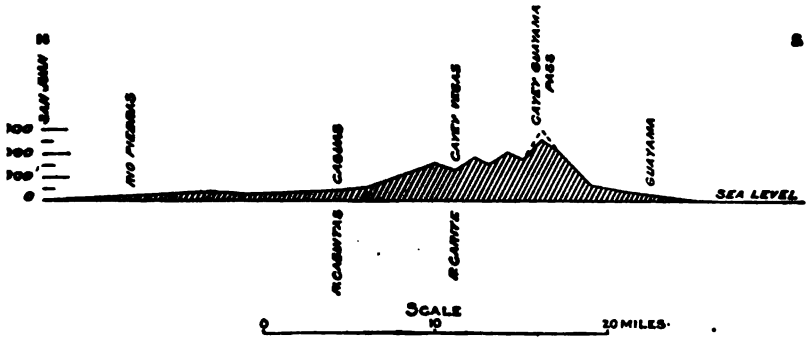


FIG. 2.—Section north and south through San Juan.

yey at an altitude of 1,200 feet, and is thence more gradual through e rolling country drained by the Rios Loiza and Guayanabo, in the ighborhood of Caguas, Aguas Buenas, and Comeiro.

To the west of Aibonito the main dividing range rises sharply in a oader and more strongly maintained sierra, which has here the name rdillera Central. The passes through the Cordillera attain altitudes 2,500 to 2,800 feet, but upon it there are no marked peaks, the ghest summit scarcely reaching 3,300 feet in altitude. The Cordil-a Central is interrupted to the north of Ponce in a pass 2,320 feet altitude, leading to Adjuntas, at the head waters of the Rios Portu-

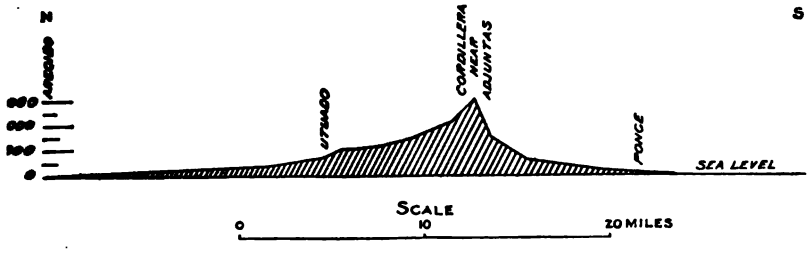


FIG. 3.—Section north and south through Ponce.

es and Arecibo. A cross section of Puerto Rico from Ponce to ecibo (fig. 3) does not differ materially from that between Guayama d San Juan, the chief points of difference being that the slopes to e south do not fall away quite so abruptly as farther east, while to e north the slope is decidedly more gradual than in the neighbor-od of Caguas.

West of Adjuntas the sierra rises abruptly to El Guilarte, altitude 3,608 feet, which is the second mountain on the island in height. Here the character of the main dividing mountain range is abruptly changed. A number of rugged spurs branch northwestward toward Lares and Las Marias, westward toward Hormigueros, and southwestward toward San German. These spurs have not the continuity of the main mountain range from which they spring, but are broken up into a number of irregular ridges and peaks of extremely rugged aspect.

The series of controlling mountain ranges as sketched above are of the same geologic time and origin; all are of mixed volcanic and sedimentary origin, consisting chiefly of hornblende-andesites, gneiss, and tuff, embedded in which, but found at altitudes generally below 2,000 feet, is a compact blue limestone of Cretaceous time.

Abutting against the foothills of these commanding sierras, and forming secondary topographic features of striking importance, are a number of varied forms found at different portions of the island and owing their shape and mode of weathering to their geologic origin. On the north coast, between Arecibo, San Juan, and Fajardo, the main summits fall away rather abruptly to elevations of between 1,000 and 1,500 feet; they then continue as radial spurs, sloping gently to the northward and interrupted by numerous undulations, culminating often in peaks of considerable altitude and prominence.

These are separated by the principal rivers draining the interior, which flow generally to the north, but are deeply indented in the surface of the country. Thus within 5 or 6 miles to the north of the main summits the river bottoms are at altitudes of about 1,000 feet, while the summits of the ridges above are at elevations of 2,000 to 2,500 feet. Again, within 5 miles of the coast, the river beds are at elevations of 50 to 100 feet above sea level, while the summits of the dividing ridges reach altitudes of 1,000 to 1,500 feet. These dividing ridges are often maintained to the ocean shore, are high, narrow, and A-shaped, and are separated one from the other by deep V-shaped valleys eroded by numerous streams flowing in every direction throughout the interior of the island.

COASTAL TOPOGRAPHY.

The topography of the coast border consists of narrow margins plains extending here and there up the river valleys for from 3 to miles. These flat coast lands are called playas, and their continuit is broken on the northeast, southeast, and northwest by spurs of th main mountain mass which plunge directly into the ocean. The encircling plains and playas are, moreover, irregularly broken by lo coast hills. On the south these are all of limestone and are 200 to 4 feet in height; on the north they are a series of old coral reefs erode [illegible]ached hills of 50 to 150 feet in height. Thus the coast top

raphy may be divided into three types, distinct from the central mountain mass, consisting of (1) the playas or plains; (2) coast hills and parting valleys which separate the latter from the foothill spurs of the central mountains; and (3) a highly eroded coral plateau, an intermediate topographic type beween the sierras and the coast topography, found in the northwest portion of the island between Arecibo, Lares, and Isabela. The ascent to this latter from the west in the neighborhood of Aguadilla is abrupt and the surface of the plateau is gently rolling. This is cut by the more important streams, which have eroded abrupt canyon walls 150 to 200 feet in height. To the south this is topped by a higher series of sugar-loaf shaped buttes of coral, the summit elevation of which is about 1,200 feet.

Still another topographic type, distinctive only in that it is an exaggeration of the limestone hills and parting valleys found elsewhere, is that between Mayaguez, Cabo Rojo, and Ponce, in the southwestern corner of the island. Here the sea is bordered by a low ledge of coral, capped by a heavy stratum of hard limestone. This is tilted upward

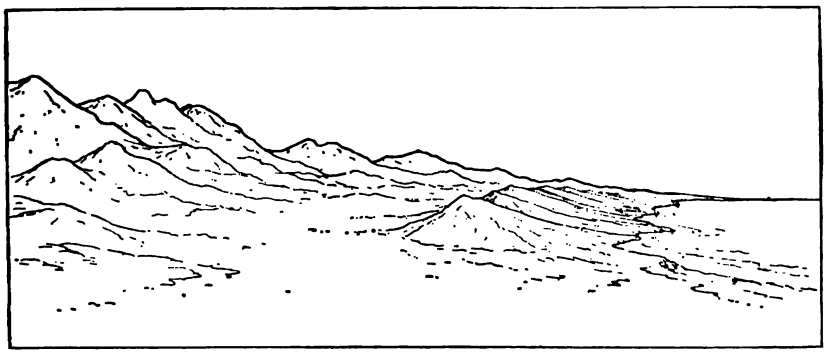


FIG. 4.—Cordillera Central, parting valley, coast limestone hills, and playa at Ponce.

so as to rise from the southwest toward the center of the island, and is separated from the main sierra by two long and fertile parting valleys.

Elsewhere on the island, and especially well developed from Ponce eastward to beyond Guayama, the low coast hills of limestone have their east-west continuity broken by the playas at the stream mouths. They are also separated from the main sierra by short, narrow parting valleys, eroded by branches of the streams which drain the main summits (fig. 4). Some of these hills terminate abruptly at the sea in bluffs 100 feet in height, while the parting valleys which border them on the north have elevations of 100 to 200 feet, their summits reaching altitudes of 500 to 1,000 feet.

PHYSIOGRAPHY AND SCENERY.

In order that the topographic forms of the island may be more clearly comprehended, the following detailed description is given of some of the more striking surface characteristics along the route traveled.

The country traversed—by railway eastward from San Juan as far as Carolina, and thence by military road to Rio Grande—is typical of the larger playas reaching from the sea margin to the back coast border. This is a comparatively flat alluvial plain (see Pl. II, *A*) about the mouth of the Rio Loiza and its branches. It has been built up largely through the aid of mangrove growth, which has encroached upon the sea and retained the alluvium brought down by the streams. Between Rio Piedras and Carolina this alluvial plain is 5 miles in width from the seashore. Its greatest width, near the mouth of the river opposite the town of Loiza, is 9 miles. In the total air-line distance of 20 miles from near San Juan to beyond Rio Grande this plain is cut by three large lagoons, and the area of this magnificent stretch of agricultural land is about 100 square miles. The whole is well cultivated in a rich forage grass, called "Guinea grass," and in sugar cane.

To the south of the edge of this playa the hills rise rapidly in broken spurs, which radiate from the summit of the Sierra de Luquilla. This playa land is, moreover, not an unbroken plain. It is comparatively level, however, rising from a few feet to about 60 to 75 feet above sea level. The apparently dead level of this playa is interrupted by occasional low, bluff-topped hills of coral rock (see Pl. II, *B*), which have not been entirely eroded away.

A journey southward from Canovanas, up the river of that name to the summit of the Sierra de Luquilla, brings one immediately into the roughest of the highly eroded and rugged mountains which are so characteristic of the island. Cart roads extend up this river, as well as up all the other more level streams, until the diminished width of the gorge through which it flows and the roughness of the country cause them to be superseded by trails. The river flows over a rough, rocky bed and between steep slopes (see Pl. II, *C*), which are thickly covered with natural and cultivated vegetation. The cart road and the trail ford the river fifteen or twenty times in a distance of about 6 miles, due to the sharp curves of the stream between the confining mountain slopes. At the end of that distance, at an elevation of about 250 feet, the gorge has become so narrowed that the trail leaves it and climbs abruptly, in 2 or 3 miles, to an altitude of 1,350 feet. In all directions branch trails lead up the steepest slopes to the habitations of the peasants, who are everywhere engaged in the cultivation of the various crops which thrive best in each particular locality. (See Pl. II, *D*.)

The military road from San Juan to Caguas passes through a hilly depression, between the western terminus of the Sierra de Luquilla and the northern spurs of the Cordillera Central. The divide between the drainage basins of the Rios Loiza and Bayamon is crossed at an altitude of but 375 feet. At Caguas a broad mountain valley on the head waters of the various branches of the Rio Loiza is entered at an altitude of 230 feet. The slopes in every direction are not abrupt;

A, CAROLINA PLAIN, WITH EL YUNQUE IN DISTANCE

B, PLAYA AT MOUTH OF RIO LOIZA.

C, RIO CANOVANAS.

D, FOOTHILLS OF SIERRA DE LUQUILLA, SHOWING FIELD AND COCOANUT TREES

A, VIEW WEST FROM CAYEY DIVIDE.

B, RIO JACAGUAS NEAR JUANA DIAZ.

A, VIEW WEST FROM CAYEY DIVIDE

B, RIO JACAGUAS NEAR JUANA DIAZ.

miles in dimension, and through it winds in great serpentine curves the Rios Caguitas and Turabo. The former makes a long coil about El Monte, a lone hill 300 feet in height which occupies the center of the valley. (See Pl. IV, *B*.) Among the higher summits about Cibonito the country still has the same picturesque aspect, the same pleasantly pastoral appearance, accentuated only by the immensity of the slopes. From the higher summits the Atlantic Ocean is in plain view to the north and the Caribbean Sea to the south. Every detail of topography may be seen for miles in all directions, as though one were viewing a model map.

Beyond Cayey and thence to Coamo the great mountain masses rise to such sheer heights or descend so abruptly to the bottoms of great gorges as to be imposing in the extreme. Between Coamo, Juana Diaz, and Ponce the aspect of the country is entirely dissimilar to that seen elsewhere on the route. The military road skirts the southern slopes of the Cordillera Central and remains at a fairly constant distance of 5 miles back of the coast. It crosses six of the more important rivers which drain the southern slopes (see Pl. III, *B*), yet at no place does it attain an altitude greater than 250 feet above sea level, nor at the stream crossings is it less than 100 feet above sea level.

To the north the masses of the main sierra rise abruptly in great jagged spurs, with fairly uniform slopes. In all other directions the country is a rolling plain, broken by numerous ridges and detached hills. (See Pl. VI.) These are separated by small and level parting valleys, relatively broad and all under cultivation, chiefly in sugar cane. (See Pl. X, *C*.) The entire south coast is 1 to 7 miles in width, averaging about 5 miles, and from east of Guayama to a little west of Ponce is of this same general character. The sea is bordered by coral reefs, sometimes, especially near the river mouths, by small playas, and back of these, often quite close to the coast, rising northward there is a tilted limestone table-land. This is eroded into detached hills and ridges both by the north-south primary drainage and by the east-west lateral drainage which forms the parting valleys. There is thus seen to be a large area of excellent agricultural land along the coast, but this is generally so arid as to require irrigation for the cultivation of such thirsty crops as sugar cane. Small fruits and vegetables are grown without irrigation and all the hills are covered with forage grass. The mountain slopes on this side, however, are not nearly so extensively cultivated as on the north side. In addition to the disadvantage of unfavorable soil and insufficient precipitation comparatively little foothold is given to vegetation on their steep sides.

On the road from Ponce to Adjuntas, which ascends first the general course of the Rio Magueyes and near the summit crosses to the *head waters* of the Rio Portugues, one has an almost south-north cross *section of* the sierras, as compared with the diagonal section viewed

A VIEW BETWEEN CAYEY AND ABONITO SUMMIT.

B CAGUAS VALLEY AND EL MONTE

C HILLS ALONG RIO ANASCO

D VIEW NEAR SUMMIT OF ADJUNTAS PASS

A. SCENERY SOUTH OF AIBONITO SUMMIT

B. BENT MANGO TREES, SAN JUAN

raveling southwestward from Aibonito to Ponce. The topographic racteristics are identical with those seen, however, on the latter e. Four miles to the north of Ponce the elevation is but 50 feet. way climbs for the next 3 or 4 miles through sloping foothills to altitude of 400 feet. Thereafter, in 2 miles horizontally, the ascent e main ridge dividing the two rivers is to an altitude of 1,720 feet. h equal abruptness the main summit (see Pl. IV, *D*) is reached ut 15 miles from Ponce, at an altitude of 2,320 feet.

djuntas is on the northern slope and on the head waters of the Arecibo. About it the topographic characteristics are in all pects similar to those observed at Aibonito. But a few miles to southwest rises El Guilarte; to the north are seen long radial spurs he main sierra, which are separated at Utuado by the valley of the cibo; northwestward another long spur extends to and beyond es and San Sebastian to the western sea at Aguadilla. This sepa- s the head waters of the various rivers which empty into the north- ocean between Arecibo and Aguadilla and the drainage of the s Culebrina and Prieto, which flow into the western sea at Agua- a and Añasco, respectively. The spur which extends to the south- t, and on which are El Guilarte, Las Sillas de Calderon, Tetas de ro Gordo, and other prominent peaks, separates the waters of the s Prieto and Blanco from those of the Rio Guanajibo.

is thus seen that the neighborhood of Adjuntas is, as the name lies, the dividing point of the main sierra, which has extended unbroken crest from its easternmost summit at El Yunque. At point it is separated into a number of spurs of almost equal minence, which reach the western coast with several ramifications, most prominent of which is necessarily that containing the group ummits above named.

he various trails leading westward from Adjuntas toward Las ias and Lares follow the head waters of the Rio Blanco or Rio to for a short distance. Thence they climb to altitudes of about O feet at the summits of the divide separating the various drain- lines. These divides are high A-shaped ridges, separated by great aped canyons with relatively smooth slopes 1,000 feet in depth, vell covered with vegetation. Everywhere throughout this region, the highest summits and in the bottoms of the most profound ges, are found the habitations of the peasantry, who gain a com- able living from the cultivation of coffee and of fruits and vege- les.

rom the summit above Lares (Pl. VII, *A*), the altitude of which ,000 feet and which is called La Torre, a magnificent view is had he surrounding landscape. To the east, south, and southwest are t masses of the most rugged mountain forms. In the first direc- the high and serrated northward spurs of the Cordillera Central n the horizon line. To the south one looks across the gorge of the

Rio Blanco, 1,500 feet in depth and but a mile distant, whence the eye climbs a space of but a few miles to the highest summits of El Guilarte and Las Sillas de Calderon. To the north and northwest the country slopes away to the point, apparently but a few miles distant, where the sea and sky meet in a dull gray line. The topographic aspects in this direction are entirely different from anything heretofore seen. The immediate foreground slopes away gradually to an altitude of about 1,000 feet in the neighborhood of Lares, beyond which, extending from the north through 80° toward the west, is a long line of sugar-loaf shaped coral hills (see fig. 5). These are but 250 to 350 feet in height, their summits reaching altitudes of about 1,200 feet. Some are covered with smooth green slopes and others have their surfaces broken by steep bluff ledges of coral. These "Piloncillos" or "Farallones," as the Spanish-American calls them, have the general appearance of a great group of conical-shaped Sibley

FIG. 5.—Piloncillos, or conical coral hills; Lares.

tents and in this locality go under the general name of "Pepino hills," though similar topographic features in other portions of the West Indies are called by the English "cockpits."

Between Lares and San Sebastian the country is generally similar in topographic aspects to the region north of Cayey and Caguas toward San Juan. San Sebastian is at an elevation of 270 feet. From it fall away toward the west the gorges of the various rivers which drain that slope, and these are separated by high ridges having altitudes of but 500 to 800 feet, rising, however, to altitudes of nearly 1,000 feet as they approach the ocean. North of Añasco a high and serrated ridge maintains its bulk to the very margin of the sea, into which it plunges with abrupt slopes. The same is true of the ridges which approach the ocean to the north of Aguadilla, and in less degree of those north and south of Mayaguez. At the mouths of the principal rivers in the neighborhood of Aguadilla, Añasco, and Hormigueros

are extensive alluvial playas similar to those already described, and highly cultivated in sugar cane.

The country traversed by the main highway from Mayaguez via San German and Yauco to Ponce has already been generally described as differing essentially in topographic characteristics from any of the other portions of the island passed over. The road skirts the southwestern slopes of the main sierra. Between it and the sea, distant in some places as much as 8 to 10 miles, are a series of low, rolling limestone hills tilted upward toward the interior and separated by two extensive parting valleys. The erosive action which has produced the long valleys marking the junction line between the foothills which parallel the main mountains promises, according to Mr. R. T. Hill, to reduce these valleys to sea level in the near geologic future, and thus to cut off from Puerto Rico a small island including the country round about Cabo Rojo and Lajas.

From Mayaguez, through Hormigueros and San German, to Sabana Grande is a great valley, through which flows the Rio Guanajibo. It is this which separates the main summits from the rolling foothills to the south, which are hereby dignified by the collective name of Cerro Gordo. Between Sabana Grande and Yauca is a low divide connecting the Cerro Gordo with the main sierra and separating the greater valley from a similar but smaller valley, which includes the lagoon of Guanica and extends from Guayanilla and Yauco to the port of Cabo Rojo. (Pl. VIII, *A*.) Still south of the valley and separating it from the Caribbean Sea is a second well-defined ridge of low limestone and coral hills.

CLIMATOLOGY.

Situated as the island is, with a middle latitude of about 18° 15′ N., which is well within the torrid zone, it is seen to be in the same approximate latitude as the City of Mexico, the Hawaiian Islands, the Sahara Desert, and Bombay, India. Because it is the easternmost of the Great Antilles, however, its climate is so tempered by the trade winds as to render it more moist and salubrious than that of any of the regions named, with the possible exception of the Hawaiian Islands.

To the trade winds primarily, and to the influence upon them of the high mountain summits in the interior of the island, are to be ascribed the moderate temperature and the peculiar distribution of precipitation which characterize this island. Though smaller in area by 1,000 square miles than the State of Connecticut, its extremes are subject to as great difference in rainfall, both in amount and occurrence, as are the extremes of the United States. The trade winds blow with unceasing regularity throughout the year, though not with such force as to be disagreeable. Their pressure is felt as wind movement but a short distance from the northern and eastern coasts,

their influence is exerted throughout the island, most perceptibly to the east and north of the mountain summits which form the watershed between the Atlantic Ocean and the Caribbean Sea. Their strength and persistence is witnessed in the shape of the trees on the north or windward coast (see Pl. V, *B*), where the trees are bent southwestward or away from the prevailing winds much as those on the southern coast of California bend eastward or landward away from the prevailing Pacific winds.

Heavily moisture laden from the warm ocean, the trade winds press against the mountains, which quickly condense the moisture they bear, and heavy showers of sudden occurrence but short duration result. Southward and westward the same winds continue to cause even more abundant precipitation at the sierra summits near the center of the island. Crossing these the winds are suddenly freed and expand, and being thus given power to carry in suspension a larger amount of moisture, they let fall but little rain over the southern and western slopes.

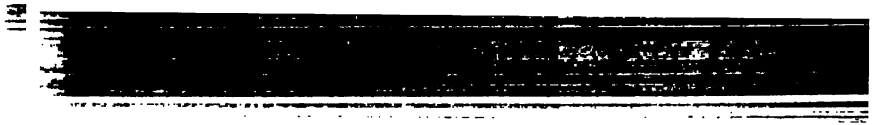
PRECIPITATION.

The above conditions are clearly recorded in such meteorologic data as has been collected by Prof. Mark W. Harrington, of the United States Weather Bureau, from existing Spanish records. According to a bulletin issued by the Weather Bureau, records for a period of twelve years show the average annual precipitation in San Juan to be 59.5 inches. This is fairly well distributed throughout the year, the greatest monthly mean (7.62 inches) occurring in November, but that amount is closely approached during the entire rainy season from April to November, inclusive. During the remainder of the year, in the so-called dry season, the mean monthly precipitation falls to a minimum of 1.8 inches in February. The persistence of rainfall throughout the year is still further accentuated by the fact that the least precipitation recorded at San Juan in any month was 0.3 of an inch in March of one year, while the greatest was 17.1 inches in August of another year.

While these figures give an indication of the range of precipitation in the neighborhood of San Juan and near the north coast, they form no criterion for the relative amounts falling elsewhere on the island. Records of observations made by Capt. Arthur C. Hansard at Hacienda Perla, published by the Weather Bureau, indicate quite different conditions there. This place is situated on the northeast coast, only about 20 miles east of San Juan, and about 3 miles from the sea, at an elevation of 460 feet. The records show an average annual precipitation of 123.4 inches during the two years 1896 to 1898, the maximum, 136.2 inches, occurring in 1897. The distribution of rainfall was similar to that at San Juan, the minimum monthly precipitation being 2.5 inches in February and the maximum 32.9 inches in *May*. During this period the greatest consecutive twenty-four-hour

A, VIEW WESTWARD TOWARD LARES FROM LA TORRE SUMMIT.

B, VIEW TOWARD LARES FROM THE EAST. COCOANUTS AND BANANAS IN FOREGROUND.



rainfall was 8.4 inches in August. In this period there averaged two hundred and fifty days a year in which over one-hundredth of an inch fell. The great differences in precipitation between two places so close together is partly accounted for by the fact that Hacienda Perla lies under the northern slope of El Yunque, the highest mountain on the island, and it feels therefore more strongly the effect of the compression of the trade winds than does San Juan, which is situated on the coast, and behind which the mountains rise more gradually and at a considerably greater distance to less altitudes than those behind Hacienda Perla. As shown by the accompanying profiles (figs. 1, 2, and 3), the highest summits back of San Juan, at the headwaters of the Rios Plata and Loiza, reach altitudes of 2,700 feet in a horizontal distance of 30 miles.

Back of Hacienda Perla an altitude of over 3,700 feet is attained in less than 3 miles horizontally. Farther inland to the south and west of San Juan, under the summits of the main sierra in the neighborhood of Cayey, Aibonito, Barros, and Adjuntas, the precipitation is considerably greater than at San Juan, though not nearly so great as at Hacienda Perla. This is because these points are at a much higher elevation and are nearer the mountain crests than is the capital city, and feel more directly their effect upon the trade winds.

Apparently great as are these extremes of precipitation, they are small as compared with those between points on the south and north coasts. According to data gleaned from Spanish records, it appears that the average annual precipitation on the southern slope of Puerto Rico is but 20 inches, against 55 to 123 inches on the northern slopes. This amount, however, is most irregularly distributed. There is said to be an authentic record at Guayama, immediately south of San Juan, of thirteen months, chiefly in the year 1893, when not an inch of rainfall was recorded. The records at Cabo Rojo show one period of three years in which no rain fell.

Such great changes in precipitation, as well as in geologic formation and soil composition, result in great differences in the flora of the two coasts. Puerto Rico may be said to have a humid as well as an arid side. This is evidenced not only by the perpetual muddiness of the roads on the north slope as compared with their dry and dusty surfaces on the south, but especially by the vegetation and the regimen of the rivers.

On the north, nearer the mountain summits, the flora is always bright and verdant and of true tropical luxuriance (see Pl. IV, *A*), and the rivers carry large volumes of water. In the south, especially near the southwestern extremity of the island, the trees are dwarfed hardwoods; cacti, century plants, and acacias abound, and the vegetal as well as the topographic characteristics are similar to those of the semiarid Southwest of the United States. (See Pl. VIII, *B*.) The river beds, moreover, are almost dry and are full of rocks and bowlders.

These two salient facts, the diversity of climate and of soil composition, must be kept prominently in mind in any consideration of agricultural or water resources or of highway construction. They make it clearly evident that any generalizations on these subjects for the whole island are valueless, and, small as is the area, each particular locality must be considered by itself in discussing the development of its products. It is scarcely necessary to add that while irrigation is not practiced on the northern side of Puerto Rico, all the wealth of sugar produced on the semihumid side is dependent for its successful cultivation on water supplied by irrigation.

TEMPERATURE.

The temperature is very evenly distributed in height and range, and is in marked contrast to the variations in precipitation. It need not be discussed in detail, as it has little bearing upon problems connected with the agricultural resources, the development of irrigation, or the construction of highways. It is chiefly interesting because of its uniformity and the resulting healthfulness of the climate. The highest recorded temperature was that of 100.8° F., in the month of May, and the lowest but 56.1°, in the month of December. Rarely, indeed, has a temperature lower than 57° been recorded, and as rarely one above 97°. The average annual temperature recorded in San Juan during twelve years was 78.1°, the lowest mean monthly temperature being 74.7° in February of one year and the highest mean monthly temperature 81.1° in June of another year, a range of but 6.4° in extreme mean monthly temperatures.

At Hacienda Perla the average annual temperature is 76.9°, or but 1° lower than at San Juan. At the same place the maximum recorded, 95°, is lower by 5°, and the minimum is higher, 61°. Elsewhere in the mountains the range of temperature is about the same. On the south coast, as in the sierras, there are no authentic records, but there appears to be great uniformity of temperature everywhere on the island.

HYDROGRAPHY.

In spite of the smallness of the island, and the consequent short length of its rivers and restricted areas of their catchment basins, it is unusually well watered, because of the comparative humidity of the climate. Moreover, because of the steepness of the slopes, especially on the northern coast, and the impervious character of the clay soil which covers them, the proportion of precipitation which runs off makes these rivers of even larger volume than would otherwise be expected under corresponding conditions. Into the northern ocean flow 12 streams of considerable magnitude; toward the west coast flow 4 of relatively equal size; into the eastern sea flow 5 of less magnitude, and into the southern sea flow 17 of considerable size but comparatively small perennial volume. In addition, there are between 1,200

id 1,300 streams and branches of less volume, but yet of sufficient ze to bear separate names.

Since the average width of the island is but 35 miles and its extreme ngth but 105 miles, while its commanding summits range in altitude om 2,800 to 3,750 feet, it is evident that the slopes are steep, the fall the rivers great, and the velocity of their waters high. Moreover, the main summits of the dividing mountain ranges have been shown be one-third nearer the southern and eastern coasts than the orthern and western, it is also evident that such streams as flow to ne north and west are three or four times as long and drain ten to fteen times as great areas as those flowing to the south and east. The ormer have average lengths of 25 to 40 miles, measured along their tream beds; the latter have lengths of but 5 to 15 miles. For these nd the reasons already given the streams flowing north and west ecessarily have less abrupt slopes than do those which drain eastrard and southward, which plunge from an altitude of 3,000 feet to ea level within a comparatively few miles.

It is thus seen that as the island is divided climatologically into two istinct portions, it is similarly divided hydrographically, largely as a esult of the same causes—the trade winds and the topographic conguration of the surface.

Of the twenty-eight larger rivers above enumerated, each has its ource high among the summits of the Cordillera Central. Those flowng to the north and west are characterized by precipitate descents f 1,000 to 2,000 feet in the first 5 miles of their head waters. Therefter they flow more leisurely and with consequent increased size to rithin 5 miles of the coast. There they emerge practically at sea evel in long, meandering curves through the alluvial playas about heir mouths. Because of the lowness of their grades near the coast nd their resulting low velocity, all are of considerable width and noderate depth in the playa levels. A few miles inland, where they low over steep, rocky beds, their channels are narrow and often coned by precipitous rocky walls, their width is of but comparatively ew feet, their depth often less than a foot, and their velocities so igh as to render them veritable mountain torrents (see Pl. II, *C*).

On the southern coast the larger rivers have bed widths as great as hose entering the northern and western coast. Their lengths, howver, are so short for the same fall that they are not characterized by he long stretches of low, meandering grade found near the coast in he playas to the north. They emerge, on the contrary, from the mounains at but 3 to 5 miles from shore line at altitudes of 200 to 400 feet, nd as a result this elevation is passed with comparatively steep lopes over rocky or bowlder-strewn channels. Above these coastal tretches and within the mountains the lengths of the rivers are so hort for the relatively great heights which they fall that their dimenions are little greater than those of the smallest brooks which flow rom the hill summits in the Rocky Mountains.

The rivers of the north and of the west are more like the streams of humid regions in the United States, as their perennial discharge is always fairly well maintained. The larger of these rivers have at low-water stage bed widths of 150 to 200 feet, average depths of 2 to 4 feet, and minimum discharges of 250 to 1,500 second-feet. (See Pl. VIII, *C*.) In time of flood, although these rivers attain maximum discharges of 10,000 to 20,000 second-feet, these volumes are not greatly in excess of the flood discharges of the rivers of the southern slope.

The width of stream bed of the southern rivers is often as great as that of those entering the northern coast, but owing to the infrequency and small amount of the precipitation and the relatively porous character of the soil reducing the percentage of run-off, as well as to the smallness of their catchment basins, they discharge minimum volumes of but 50 to 100 second-feet. These streams resemble the rivers of our Western plains in that their beds are nearly dry the larger part of the year (see Pl. VIII, *D*), but are yet of sufficient capacity to discharge great volumes during the sudden floods to which they are subject. The beds of these rivers, even near the coast, are bowlder strewn and are from 100 to 300 feet in width. The depth of their banks is 10 to 20 feet, yet the minimum surface widths of such streams is but 50 to 100 feet and their average depth one-half to 1½ feet during their minimum discharge. In maximum flood such streams reach discharges aggregating 5,000 to 10,000 second-feet, in some cases even more, as shown by their wide, rocky, dry beds.

To convey a clearer idea of the size and regimen of the rivers of Puerto Rico, the following results of rough gagings of such streams as were examined in the preliminary reconnaissance of the island are given. As these streams were observed in the middle of the dry season their discharges may be taken as showing the average minimum volumes which they carry.

The Rio Loiza, probably the largest on the island, was gaged near Carolina, about 15 miles east of San Juan. Its surface width was 220 feet, its average depth 3 feet, and its minimum discharge 1,600 second-feet. (See Pl. VIII, *C*.)

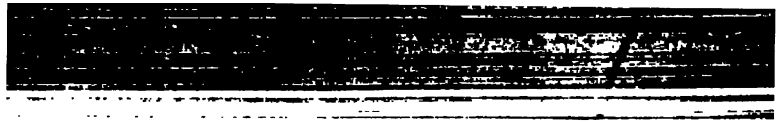
The Rio Canovanas, above its junction with the Loiza, 5 miles east of Carolina, has a bed width of 60 feet, average depth 2 feet, average velocity about 5 feet per second, and discharge 600 second-feet. (See Pl. II, *C*.) This amount is to be added to the discharge of the Loiza to give the volume of the latter at its mouth.

At Caguas, about 20 miles by road south of San Juan, and 230 feet above sea level, the Rio Caguitas, one of the principal branches of the Loiza, flows in long, meandering curves through a level alluvial valley, and carries a minimum volume of about 50 second-feet. A few miles beyond, and in the same valley, the Rio Turabo, another branch of the Loiza, is of similar character and discharges an equal volume.

The Rio Carite, at the crossing of the military road, 36 miles from *San Juan*, and in the Vegas or plain of Cayey, has an elevation of

A. PARTING VALLEY ABOUT AND HILLS BACK OF YAUCO.

B. ARID FLORA NEAR LARES.



out 1,180 feet above sea level. This is a branch of the Rio Plata, d its discharge at this point is about the same as those of the two st-mentioned streams, namely, 50 second-feet, though because of greater altitude, and consequently greater slope, the cross section its channel is smaller.

The Rio Plata, at a point 4 miles northwest of Cayey, at an altide of 810 feet, has a bed width of about 100 feet, a depth of 1½ feet d a discharge of 230 second-feet.

South of the main divide at Aibonito, the Rio Calabasas, 4 miles st of its junction with the Rio Coamo at Coamo and at an elevation 480 feet, has a velocity of 3 feet per second and a discharge of but second-feet.

The Rio Coamo, at the city of that name, and at 360 feet above sea vel, has a bed width of 100 feet, though its surface width is somehat less. Its depth is but 4 inches and its discharge 100 second-feet.

The Rio Descalabrado, halfway between Coamo and Juana Diaz, at elevation of 260 feet, has a comparatively dry bed of 120 feet width. velocity is but 2 feet per second and its discharge 40 second-feet. e Pl. IX, *A*.)

The Rio Jacaguas at Juana Diaz, elevation 160 feet, has a bed width 180 feet, a minimum surface width of 50 feet, and a discharge of second-feet. (See Pl. III, *B*.)

The Rio Portugues at Ponce has a bed width of 175 feet, yet its nimum discharge is but 60 second-feet. (See Pl. VIII, *D*.) Its al available discharge is considerably greater than this, but the nainder of its volume is diverted a few miles above for irrigation d for the water supply of Ponce. The same is in a measure true of Rio Jacaguas, a portion of the discharge of which is utilized for igation above the military road.

The Rio Magueyes, at the crossing of the road from Ponce to Adjuns, 5 miles north of Ponce, elevation 400 feet, has a minimum discharge 35 second-feet.

The Rio Portugues, at the crossing of the above-named road, near headwaters, 9 miles north of Ponce, elevation 1,000 feet, has a minium discharge of 25 second-feet.

The Rio Arecibo, near its headwaters, at Adjuntas, altitude 1,440 et, has a minimum discharge of 40 second-feet. A few miles lower wn, at Utuado, its discharge is 100 second-feet. This river, like e others described, discharges relatively increased volumes in its wer reaches near the coast.

The Rio Yahueca, one of the headwaters of the Rios Blanco and etro, or, as they are called near the coast, the Rio Añasco, has, at elevation of 1,440 feet, about 5 miles west of Adjuntas, a minimum charge of 20 second-feet.

The Rio Blanco, into which the Rio Yahueca discharges, at an eletion of 1,350 feet, about 8 miles west of Adjuntas, has a minimum lume of about 50 second-feet.

The Rio Culebrina, near the middle of its course at San Sebastian, elevation 140 feet, has a bed width of 125 feet, a considerably less surface width, a velocity of 4 feet per second, and a minimum discharge of 100 second-feet.

The Rio Añasco, halfway between San Sebastian and Añasco, at a point about 8 miles from the latter city, has, at an elevation of 80 feet, a bed width of 150 feet, a surface width of 75 feet, a depth of 1½ feet, and a discharge of nearly 600 second-feet. (See Pl. IX, *B*.) The same river below the city of Añasco flows through a level playa and has an easy, meandering course, its grade being so low as to render its velocity very slow. Its surface width is here about 200 feet, its depth 4 to 8 feet, and its discharge about 1,000 second-feet.

IRRIGATION.

It is evident that all the crops which the soil will produce can be grown over three-fourths of the extent of the island with the aid of the abundant rainfall alone. The other one-fourth, including all the region near the coast and from Cabo Rojo on the extreme west to beyond Guayama on the east, must be irrigated if the soil is to produce the full measure of crops of which it is capable. The total area of these irrigable lands is, however, relatively small. A portion of this one-fourth, or, in round numbers, of the 800 arid square miles, is included within the steepest portions of the southern mountain slopes. Another portion consists of the rugged foothills which, as they rise in detached summits, it is impossible to reach with a gravity water supply. Still another portion of this area consists of the alluvial playas, which produce fairly abundant crops with the aid of the moisture which they draw through their roots from a soil which is but a few feet above the level of the sea. Of the 450 square miles included within the southern back-coast border, perhaps 150 consist of playa lands which need not be irrigated, and 300 more consist of detached and inaccessible hills and of the precipitous slopes of the sierra. There remain, accordingly, perhaps a total of 150 square miles which would add to the agricultural resources of the island if artificially provided with water.

The soil on these lands is in every case of the very best kind for agriculture with irrigation. It is usually an open, porous, limestone soil of sandy and gravelly texture, mixed with a little earthy loam. It is fairly deep and is underlain by a porous limestone or coral, which affords the best drainage and probably renders it safe from the danger of producing alkali. Much of it is already under cultivation in maize, beans, pease, and other lentils in the southwestern extremity of the island, and small vegetables and fruits elsewhere.

While the precipitation is insufficient, the perennial flow of the streams is unusually abundant for a land requiring irrigation. The *minimum* discharges of these streams where they would be diverted in

A. RIO DESCALABRADO.

B. RIO AÑASCO

C. REGULATOR GATE AND DITCH.

D. WING DAM.

e foothills are moderate in amount and yet nearly sufficient for the igation of such areas as they command. Moreover, the flood disarges of these streams occur at frequent intervals throughout the ar, but are especially well distributed throughout the summer or iny season. They afford an abundant surplus for storage. The apes of the smaller parting valleys and of the lower canyons through ich the rivers emerge from the mountains give every indication at abundant opportunities will be found, on fuller investigation, for e construction of storage reservoirs at moderate expense and at relavely small cost.

The Spaniards, who in the past have been the principal landholders, e thoroughly familiar with the requirements and processes of irrigaon as practiced in Spain. Quick to appreciate the advantages of e artificial application of water, they have already constructed umerous ditches of moderate sizes, and much of the more valuable gar land, especially between Guayama and Ponce, is cultivated clusively by the aid of irrigation. Much as has been done already this direction, there is still room for further development. But a rtion of the available water supply has been appropriated, and t a small portion of irrigable lands are artificially supplied with ter.

Such works as were noted correspond in general type to those seen Mexico, but because of the greater influence of European ideas in is island, their construction is of a more substantial character, and ore nearly approaches that prevalent in Spain and Italy. The version works are in every instance of the crudest kind, simple ing dams of rock and bowlders thrown out into the beds of the reams to direct a portion of the waters into the heads of the ditches. hese are necessarily carried away by each flood, requiring to be mediately replaced. On the other hand, the headworks, falls, gulating gates, and other dividers are constructed in the most subantial manner of massive masonry.

In strong contrast to this type of construction are the minor disibutaries observed in some of the cane fields. These were built by rners who had great grinding and boiling machinery for the treatment their cane, and were imbued to a certain extent with American ethods. They out-Americanized our Western irrigators. Their stributaries consist of a series of temporary trestles and shallow oden troughs or gutters made of lumber brought from America. hese tap the hillside ditches at such points as seem desirable, and e roughly placed so as to carry the water to such portions of the ld as immediately require it. After irrigation in such localities e trestles and troughs are removed and utilized in irrigating other rtions of the same fields. This practice is resorted to in order to ach the numerous little detached rolling hills 10 to 20 feet in maxium height, into which the surface of the sugar lands is broken. In

other localities, where practicable, these lands are irrigated by direct diversion from the main ditches of laterals dug in the earth and ramifying to every portion of the field to which gravity will conduct the water.

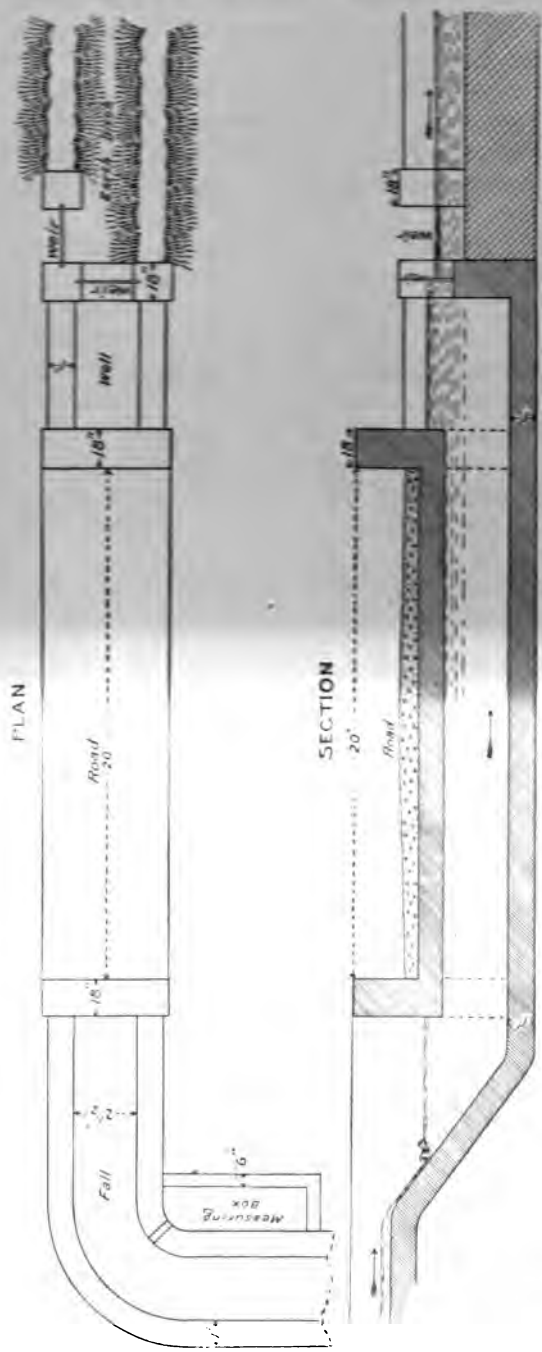


FIG. 6.—Inverted siphon carrying ditch under military road.

Immediately to the west of Juana Diaz the most important irrigation work noted on the island is a ditch from the Rio Jacaguas. The point of diversion is in a narrow gorge, well up in the foothills, about 5 miles above the military road. The ditch thence is about 5 feet in width at the top, 3 feet in depth, and is excavated in the earth slopes of the hillsides, around which it is well graded. This ditch is divided into numerous distributaries, all of the simplest earth construction, which convey its waters to every part of the cane fields.

Farther west another irrigation ditch is carried under the military road in an inverted siphon of masonry (see fig. 6), which is similar in all respects to such structures seen in India and southern Europe.

The width of the masonry channel at the entrance of the siphon is but 2½ feet and its extreme depth 18 inches. The water

es down an incline at an angle of about 45° to a depth of about 6 feet ɔw the level of the ditch bank, and is carried thence under the d in a rectangular masonry conduit. Near the entrance to this te is a little masonry measuring box 3 inches in depth, from ch water flows through a lip in the top of the conduit. The walls :he main conduit are a foot in thickness, and at their exit on the er side are buttressed by square blocks 18 inches in cross section. ;hese are grooves for inserting flashboards, by which the amount water passed into the canal beyond can be measured as over a

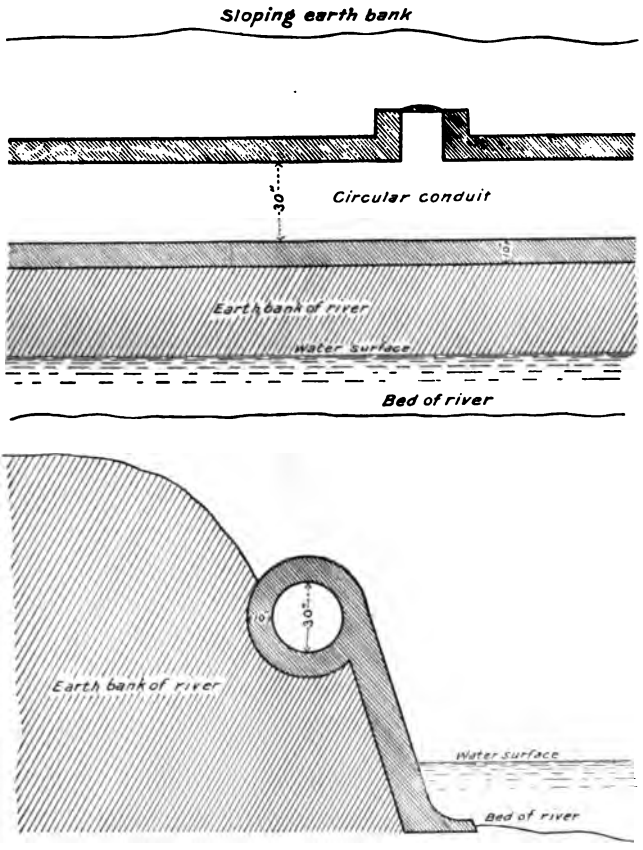


FIG. 7.—Masonry conduit and retaining wall; longitudinal and transverse sections.

r, while at the same time the supply is regulated. (See Pl. IX,

Below this a lateral is diverted through gates identical in type. ſear this place was seen a rough wing dam of rock, which diverts tream into a substantial masonry conduit (see Pl. IX, *D*), whence s led along the banks of the river through a circular masonry e 30 inches in diameter and 10 inches thick (see fig. 7), in many ces close to the river bank. To protect it from the erosive action

of floods, the conduit is supported on a heavy retaining wall of masonry until at some distance a sufficient grade is attained to carry it away from the banks of the stream. (See Pl. X, *A*.)

AGRICULTURAL LANDS AND SOIL.

The parting valleys, and especially the playa plains, are often quite extensive, and constitute the chief portion of the more valuable sugar and grass lands which border the entire coast. The larger of these agricultural plains are to the eastward of San Juan as far as Luquilla, and include wide indentations which extend up the valley of the Rio Loiza. There are smaller playas between Fajardo and Humacoa and between Guayama and Ponce. (See Pl. X, *C*.) West of San Juan the playas are not so extensive until beyond the mouth of Rio Cibua, between which and Arecibo are some large areas of playa land. Thence westward there is no coast border of any moment until Aguadilla is reached, but there, as well as at Añasco, are two fairly extensive playas. The remaining sugar lands are those in the larger parting valleys, some of which are of great extent. Those between Yauco, Sabana Grande, and Hormigueros are the largest, but some of the others contain 1,000 to 5,000 acres each.

In addition to the cultivable areas which may be added by irrigation, much waste swamp land may be reclaimed by drainage. This is especially true of the playa lands about the coast lagoons and of some of the swampy valley lands near the head waters of the Rio Loiza and Rio Plata, which are now chiefly covered with guinea grass. (See Pl. X, *D*.) One such swamp alone, near Guanica, contains 8,000 acres of reclaimable land belonging to the Government.

There are two other distinct types of agricultural lands on the island. These are found in a few small alluvial valleys on the upper courses of the rivers, as at Caguas (see Pl. IV, *B*), Cayey, and Sabana del Palmar, and in the main mass of fruit and coffee land on the slopes, reaching even to the crests of the highest summits of the sierra. The mountain valleys appear frequently to have been old abandoned lake beds, and are extensively cultivated in forage grass and in tobacco. The most interesting agricultural feature of the island is, however, the steep slopes of the main cordillera, which are everywhere cultivated and are mantled with sufficient depth of soil to give firm hold to the luxuriant vegetation with which they are covered. (See Pl. XI, *A*; text fig. 8, on page 37; and Pl. IV, *C*.)

The soil of Puerto Rico, in physical and chemical composition, is of two kinds. It is these differences which furnish the most radical changes in flora observed on the north and on the south side of the island, modified, of course, by altitude to a less extent and by precipitation to the greatest extent. Primarily the soils are either of calcareous or of clay origin, the result of decomposition of the underlying rock.

A. RIVER BED AND MASONRY CONDUIT.

B. IRRIGATION DITCH IN EARTH.

C. SUGAR LAND NEAR PONCE.

D. GUINEA GRASS, CAGUAS VALLEY.

[redacted]

Geologically, the mountain portion of the island is, according to Mr. T. Hill, composed chiefly of basic igneous rocks, as tuffs, conglom-ates, and ledges or dikes of diorites and hornblende-andesite, all volcanic origin. Included within this mass and interbedded with are two distinct limestone formations; one, found near the crest the island, is a black shaly limestone of over 1,000 feet in thick-ss; the other is a light-gray crystalline limestone, which outcrops on southern and western slopes between Ponce and Cabo Rojo. The ls which weather from the former of these limestones furnish the st tobacco lands. Those which have weathered out of the second these limestones are of little agricultural value, and on them the ligenous flora is noticeably different from that grown on the former. The main mountain masses are heavily covered with soil of a deep-l arenaceous clay. This is the result of decay of the volcanic rocks ich have been rapidly decomposed under the influences of perpetual isture and heat. To the tenacity of this soil the interior of Puerto co owes its power to retain vegetable growth on its deep slopes even er they have been deforested.

The soils of the playas are entirely of alluvium washed down from mountain formations and mixed with detritus from the adjacent estone hills. These playa soils are reddish-black in color, except the northwestern portion of the island, where they are derived m decay of the pepino hills and are black and calcareous. These ya soils are of sandy loam, well adapted to root penetration, and cellent for cultivation because they are open, porous, and there-e well drained.

OLD FIELDS AND FERTILIZERS.

In many portions of Puerto Rico the lands have been overcultivated hout fertilization. Such lands are now abandoned and have some-at the appearance of the "old fields" of the Southern States. On limestone hills of the southern coast they are covered with a short ss and resemble the sheep-grazed hills of New Mexico and western nsas. (Pl. VI.) These worn-out lands, or, as they are called in the tish West Indies, "ruinates," are found scattered throughout the ntry, and furnish one of the most interesting problems connected h scientific agriculture in the opportunities they present for recla-tion.

Excellent fertilizers are found well distributed throughout the nd, and the value of these will ultimately be ascertained and their extended. The most abundant of these is a greensand marl of ene age, found extensively in the northwestern portion of the nd, between Lares and San Sebastian, and also in the neighborhood Carolina, at the northeastern extremity of the island. This marl pears to be rich in phosphates and is not unlike in general appear-e the marls of New Jersey. Next in value as fertilizers are large

deposits of guano on Mona Island, just off the west coast, and smaller deposits in caverns on the west coast and near Ponce. Elsewhere throughout the island are great beds of shell and chalk marls and of lime phosphates. The lime marls are abundant everywhere around the coast, and gypsum marls occur in the neighborhood of Ponce.

AGRICULTURAL PRODUCTS.

The soil of Puerto Rico is so deep and fertile, the precipitation so abundant and well distributed, and the temperature, though tropic, so mild as to render it possible to cultivate almost all the land on the island. Moreover, almost every foot of it is now or has been under cultivation. It is essentially the land of the small farmer, because, limited as the island is in extent, the official records show that it is divided into 36,650 individual holdings. These are distributed as follows: Tobacco plantations, 66; cattle ranches, 240; coffee plantations, 360; sugar plantations, 435; small coffee farms, 4,185; small farms of mixed coffee, fruit, and vegetables, 4,375; small fruit and vegetable farms, 16,990. At least 21,000 of these holdings are of the smallest kind, being owned by the poorer peasantry. Such holdings range in size from 5 to 50 acres, rarely reaching the latter amount. The remaining 5,000 holdings are from 100 to 5,000 acres or even larger. The greater proportion of these are relatively small and are devoted chiefly to the cultivation of coffee, the larger ones being mostly cultivated in sugar.

So fruitful are the soil and climate that the people pass an indolent and lazy existence, even to a greater extent than is observable elsewhere in Spanish America. Outside of the few large plantations the people are unacquainted with any agricultural implement other than the machete, a short thick sword, which serves all the purposes of scythe, brush hook, ax, hoe, and weapon of defense. Holes are scratched in the surface of the soil in which to plant seeds or transplant sprouts. Thereafter no attention is given to the crop until it becomes necessary to gather the product either for domestic consumption or for exchange in the nearest village for such household necessities as the farm does not produce.

Abundant and well distributed as are the various crops, the island produces to but a fraction of its capacity. (See Pl. XIII.) Thus far there has been no incentive to grow such products as would have value for export, and no means have been available and no forces at work to incite the ambition of the people, and thus give them some inducement to gain a better living. They know nothing of the higher arts of civilization, and if they had more wealth than they now possess they would not know how to use it. With the higher aims which will come from association with the more active, liberal, and highly civilized people of the United States, increased energy may be exerted in

A. MOUNTAIN SUMMITS UNDER CULTIVATION.

B. OX CART.

C. SADDLE AND PACK HORSE.

D. HOGS LED BY ROPE.

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the near future in wresting from nature more bountiful and useful crops than are now cultivated.

At present such crops as are produced for exportation are limited almost exclusively to sugar and the by-products of the cane (molasses and rum), coffee, tobacco, and hides, in the order named. In value, however, coffee exceeds that of sugar in the ratio of three to one. According to the Spanish Estadistica General, the total exports for 1897 were valued at $18,574,678. These were distributed as follows:

Exports of principal articles from Puerto Rico, 1897.

	Amount, in pounds.	Value.
Cane sugar	125,323,589	$4,007,999
Molasses	25,085,069	403,519
Coffee	51,097,823	12,222,598
Tobacco	6,181,771	1,194,318
Hides	822,108	71,852
Other articles		674,392
Total		$18,574,678

In addition to the above there are several other articles of export which, like these, are all of agricultural origin. In order of importance they are: Honey, the value of the exported product being $517,746; wax; cattle, of which 3,180 head were exported; chocolate; straw hats; and a very small amount of fresh fruit.

From the above it is evident that the most valuable crop of the island is coffee. Next in importance ranks sugar and then tobacco and cattle. In addition there are cultivated, chiefly for domestic consumption, various cereals, lentils, potatoes, small vegetables, and fruits, as well as forage grasses.

Of domestic animals cattle are first in importance. These are of unusually large size, being far more powerful and heavier than any seen in Central or tropic South America or elsewhere in the West Indies, and in fact exceed in size the cattle of our Southern States. They have widespreading horns and in general appearance they resemble the range stock of Texas and the uplands of Mexico. (See Pl. XII, *B.*) Horses are abundant, but are so diminutive in size as to scarcely deserve any other name than pony. They resemble in general appearance the ponies of Cuba, but though small they are exceedingly hardy and are excellent pack animals. (See Pl. XI, *C.*)

All the heavy draft work of the island is done by oxen, which are yoked, not by the neck but by the horns, to heavy two-wheeled bullock carts made of mahogany and similar hard woods. (See Pl. XI, *B.*) Off the roads, and these are but few and inferior in quality, all produce is hauled to the markets and purchases made there are carried

back to the mountain farms on the backs of the sturdy little pack horses which climb with sure foot the steep, wet, and slippery trails. (See Pl. XI, *C*.) The method of packing these animals is that commonly practiced in some portions of South America. Most burdens are carried, not by means of pack saddles or of aparejos and lash ropes, but in wicker-basket panniers, which are hung loosely over the backs of the animals. Sacks of coffee, however, are hung loosely by sling ropes. In this way they are loaded with 150 to 250 pounds of coffee or other burden and tramp with quick, short steps over the rugged trails.

In addition to cattle and horses a very few small mules are bred; the only other domestic animals are poultry, hogs, and dogs. The poultry are of inferior breed, being chiefly raised for the game cocks, which are used in the universal sport of the people. These and the hogs, which are also of small size and of poor breed (see Pl. XI, *D*), thrive well, but are so few in number that fences are rarely built to restrain them. It is therefore a common sight to see hogs tethered by a string tied around one leg and attached to a tree or picket, and to see poultry tied in the same manner and forage much as do milch cows.

The various agricultural crops of importance are distributed in zones, depending on and clearly marking the variations in altitude, rainfall, and soil composition. Sugar cane is cultivated exclusively in the coast playas and in the parting valleys among the lower hills of the back-coast border. It grows luxuriantly, the stalks being 10 to 15 feet in height and often 2½ inches in diameter at the base. (See Pl. XII, *A*.) The cane is cut during the months of January to March, inclusive, and produces an average yield of 3 tons to the acre. It is the only crop except coffee, the latter to a more limited extent, which is cultivated with modern methods and harvested by the use of modern machinery. Heavy, imported metal plows, drawn by six to ten yoke of oxen, are used in tilling the soil and making the furrows, through which irrigation water is flowed. The cane is cut down with a blow of a machete, and the longer stalks cut into lengths of 3 to 4 feet by the same process. It is carted from the field to the sugar mill either in ox carts (see Pl. XI, *B*) or occasionally on trains of cars, hauled by oxen over railways placed temporarily in various avenues through the cane fields (see Pl. XII, *B*). The roadbed of these tramways is laid permanently, but the rails and ties are moved about as required. The sugar mills are invariably substantial brick structures containing the most modern machinery, in which the cane is crushed, boiled, and evaporated. From the mills cane sugar of muscovada grade, molasses, and rum are shipped, the last being usually distilled in the same mills.

Tobacco of excellent quality thrives well everywhere. The best varieties, cultivated in sufficient quantities for export, are grown chiefly in the valleys and the river bottoms on the head waters of the Rios Loiza and Plata. The culture of tobacco is especially exten-

A. SUGAR CANE.

B. TRAIN OF CARS LOADED WITH SUGAR CANE DRAWN BY OXEN.

C COFFEE SHADE.

D SHELLING COFFEE

The coffee plant is not unlike a tall, slender currant bush in general appearance, though it is peculiarly devoid of leaves or branches. Several stems grow from one root, and these are but three-quarters to an inch in diameter at the base, although they are 8 to 12 feet in height. They put out little, short branches with small leaves, and on these branches grow the coffee beans with exceedingly short stems, so that they appear to cling closely to the wood. The coffee berry when ripe is not unlike a good-sized red cherry. The plant begins to bear after four years, and the berry is picked during the winter months, from October to February. It yields best in seven to eight years and continues to produce for about thirty years. The berry is gathered chiefly by women and children, who empty their small basketfuls into

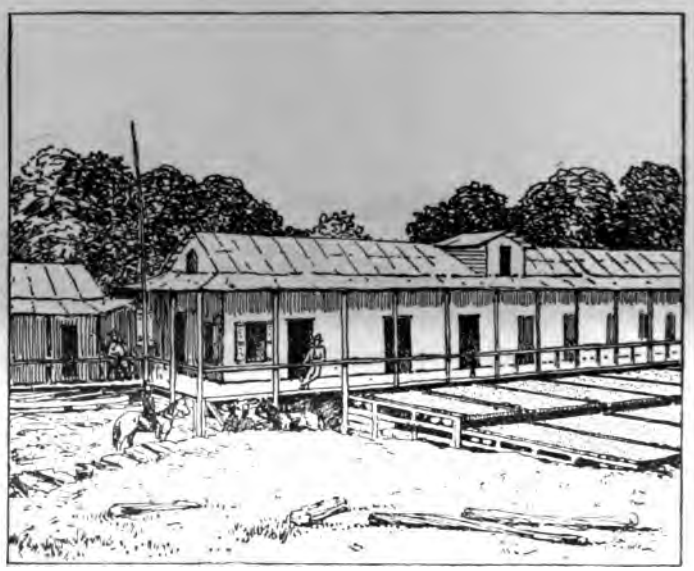


FIG. 9.—Drying coffee on rolling platforms, Pietris Plantation, Adjuntas.

larger baskets or sacks, and these are carried by men to the drying platforms, where the coffee remains in the sunshine, but always protected from rain and night dew, until thoroughly dry. The drying platforms are of two general types. The first type consists of broad, level platforms of masonry, with smooth concrete surfaces on which the berries are spread out evenly and are hoed over, and from which they are gathered and placed under cover at night or when rain threatens. The second variety of platform, that used on the larger plantations, consists of large wooden trays about 8 by 12 feet. These rest on rollers which run on tracks in such manner that when it is necessary to place the coffee under shelter the trays are rolled under the coffee house; as the trays are but 5 to 7 inches in depth, they run one above another, so that usually three trays, and sometimes more, are housed under one portion of the coffee house. (See fig. 9.) Not

infrequently coffee is dried in the streets or plazas by spreading it out on burlap sacking, which can be quickly gathered up in the form of a bag and carried away.

After drying, the berry is crushed in great wooden mortars with heavy wooden pestles, so as to break away the dried husk which incloses the coffee bean. (See Pl. XII, *D.*) Where better managed this crushing is performed in a circular trough not unlike an arastra, by means of heavy wooden wheels which are turned by animal power and sometimes by water power. After crushing, the coffee is washed and screened to separate the bean from the husk. The former is usually double—that is, there are two half beans within one berry. Not infrequently, however, it consists of one deformed bean which is egg shaped and smaller than the two halves. This variety is called "caricolillas," and is especially prized in European markets. The washed coffee beans are placed in airy rooms in the drying houses and thoroughly seasoned and dried before shipping.

The variety grown generally is of excellent flavor. As yet little of it reaches the American market, chiefly because of the export duty now placed on it and because it commands a much higher price in the European than in the American market. The better varieties are sold by the sack by commission merchants in Puerto Rico at 13 to 18 cents per pound. This is a higher price in Puerto Rico than is paid in New York by coffee importers for the best grades of Bogata, Caracas, and other fine Central American varieties. As it is not well known in the American market, importers will not offer more than 10 to 12 cents for it. Much of it, however, reaches the United States, chiefly that of the poorer grades, being shipped to Europe in transit. After it has remained some time in the bonded warehouses it is withdrawn under the names of Java and Mocha. The American coffee buyer purchases largely on the appearance of the bean, and accepts that which has a dull and lusterless appearance. In Europe, however, coffee having a bright gloss is preferred, and for this reason Puerto Rican coffee is at present extensively treated with a wash of gum arabic and charcoal or some similar preparation, which gives it this gloss. This process injures the sale of the article in the American market. Those who have used Puerto Rican coffee, however, insist that its flavor is equal to the best sold in the country, and that when better known it will command a higher price and will displace the very best of the Central American product.

Other valuable agricultural products are forage plants. The most important variety is guinea grass, a succulent plant having a blade or leaf 2 to 3 feet in height and fully one-half inch in width. It yields about 3 tons to the acre and grows quickly and luxuriantly. (See Pl. XV, *D*, and Pl. X, *D.*) Cattle and horses thrive on it and on a nutritious, leguminous plant called "malahojilla," which is a variety of the wild-pea pine. On the southern foothills the chief forage plant is

short, dry-looking grass, not unlike the Southwestern bunch or uffalo grass. (See Pl. VI.) The leaf and stalk of maize and the ods of various acacias, which are gathered green, are also used.

Maize is grown extensively in the wide parting valleys in the south-estern portion of the island. In the same region and in the beds of any of the streams which flow into the west coast, lentils are grown large quantities. There are a number of varieties of these, chiefly eans, including the green string bean and the white and liver-colored ean, which when cooked are the "frijole" of Spanish America nd the "Boston baked bean" of the United States. A lentil-like erry, which in appearance is between a pea and a small bean, and yet rows on a bush belonging to the acacia tribe, is the guadure, and his is very extensively grown for domestic consumption on the semi-umid side of the island. It occurs in a pod about 3 to 4 inches in ngth on a bush 6 to 8 feet in height. Yams and sweet potatoes are rown extensively, generally for home consumption, and Irish pota-oes thrive well, but are grown to only limited extent in some portions the uplands. Among other small vegetables are tomatoes and d pepper.

Cotton seems to flourish well, though it is not cultivated in com-ercial quantities. The cotton plants noted were almost as large as ople trees, being from 8 to 12 feet in height, with a stem 2 to 3 inches diameter at the base. (See Pl. XIV, *A*.) The flowers and pods were numerous, and the latter well filled with a long staple cotton apparently as fine as the best grown in the Southern States.

A variety of upland rice peculiar to the island is cultivated in the interior hills, and grows without irrigation or inundation. At present but little is produced, because the Spanish have discouraged its culti-vation in order to increase the importation of rice from Spain. A plant called the yautia is one of the staple vegetable foods of the people, and is grown on the humid side of the island in large fields, much as cabbage is cultivated in the United States. It is the *Caladium esculentum*, and grows to a height of 2 to 3 feet. It con-sists chiefly of wide-spreading, heavy, green leaves, 12 to 20 inches in length, in appearance not unlike those of the plantain. (See Pl. XV, *A*.) These are stewed and eaten as is cabbage or spinach, or are boiled as is okra in soups.

Another staple food is the plantain, which is baked when green, and is the bread of the people. There are many varieties of plantains and bananas, both cultivated and wild. No attempt seems to have been made, however, to grow those varieties which are in favor in the markets of the United States or Europe, and none are, therefore, exported. This should become one of the greatest of the agricultural products of the island, both for home consumption and for export, when means of rapidly conveying the same to the coast are available through the construction of good highways, and when the people

A. COTTON PLANT

B. MARKET SCENE, PONCE.

C. LOGS OF AUSUBO EN ROUTE TO MARKET.

D. REPAIRING MILITARY ROAD.

learn to produce such varieties as are in demand abroad. The seed stock at present used is poor and run out, the bananas yielding only 2 or 3 hands deep instead of 10 to 15 hands, as they must for export.

Bananas and plaintains are grown generally throughout the island. They are cultivated most extensively on the hill slopes, being rarely seen on the alluvial lands and in the valley bottoms. On the humid side of the island these plants are, with cocoanut palms, the most prominent features of the landscape. (See Pl. VII, *B.*) They are scattered on every hillside, being grown sometimes in orchards, but more generally in various portions of fields with other crops and in gardens. On the arid side of the island they are seen less frequently and at the lower altitudes quite rarely.

Another of the more abundant and valuable fruit trees is the cocoanut palm. The fruit is large sized and well flavored, and extensively consumed when green. But little is exported, though the husks are, to a moderate extent. This tree also flourishes everywhere and produces well.

Oranges, like bananas and cocoanuts, grow wild and cultivated everywhere with great luxuriance; so also do lemons and limes. A cultivated variety of oranges, which is used to a small extent in shading coffee, is unusually juicy and well flavored and is the equal of the best produced in the United States. Yet none are exported, and such few as are gathered are a drug on the home market and are sold at the rate of from two to three for one cent.

Pineapples are cultivated to a slight extent, chiefly in the southwest, about Cabo Rojo. Guayavas also are chiefly grown in the southwestern portion of the island, though they are not cultivated to the extent one would expect. From them is made guayava jelly, which is a popular confection with the inhabitants and finds also ready market in the United States. Less abundant are the aguacate or alligator pear (Persea), the guanavana, called in Central America "chiramolla" and "custard apple" (Anona); the mango, the mamey or bread fruit (Mammea), and a variety of others. All of these fruits and vegetables are extensively consumed by the people and are for sale in all the city markets. (See Pl. XIV, *B.*)

FORESTRY.

The forest resources of the island have been practically exhausted. The country has been so long densely inhabited and under cultivation that practically all the virgin timber has been removed, and some of the native trees are so rare that specimens of them can scarcely be found. Practically all of the more valuable hard woods, which are abundant in Haiti and eastern Cuba, are indigenous on this island. The whole surface of the country, especially on the higher mountain slopes, is well covered with trees. The woods consist chiefly of the artificial and natural shade trees, under which coffee is

planted. (See Pl. XII, *C*.) The more important of these trees are the guama (*Inga laurinea*), guava (*Inga vera*), bucare (*Erythrina bucare*), and maga (*Thespesia grandiflora*). These trees are of little value for their lumber, as their trunks are but 4 to 7 inches in diameter, are not straight, and branch about 10 to 15 feet from the ground, reaching a height of 30 to 50 feet. The maga has some value for timber; the wood is hard, can be worked without great difficulty, and is used to a limited extent in the construction of furniture and for similar purposes.

The most abundant of the precious hard woods is the ausubo, resembling teak or mahogany. Trees of this kind are found in many portions of the island, and it is used extensively in making bullock carts, the spokes and poles of these being always of ausubo. It is also used for beams, rafters, and upright posts in buildings. Two varieties of Spanish cedar, the hard and soft cedar, occur, but both are rare—a 12-inch plank, 1 inch thick and 12 feet long, being valued in the mountains at $1. Another of the more abundant woods is the guaraguao, which is used chiefly in making board flooring and is valued at about 50 cents per plank. Another wood employed in board flooring is the capa prieta. An excellent furniture wood, strong and hard but very rare, is the capa blanca. The mauricio is a very durable yellow wood used for parts of machinery, for the hubs of carts, and for similar purposes. A wood which does not easily decay, and is therefore used for posts and such purposes as require insertion in the ground, is the higureillo. Among other of the native woods are the nonfragrant sandalwood, laurel, ucar, algarrobo, palosanto, and bamboo. (See Pl. XV, *B*.)

All of these woods are so scarce, however, that the larger portion of the timber used in structures is imported. The most extensive import of wood is common spruce, hemlock, and pine from Nova Scotia. Many of the older buildings of the island are of native woods, but all of those which have been recently constructed have been built chiefly of imported lumber. Only two sawmills of any capacity were seen on the island, one in San Juan and the other in Ponce, and both were engaged in cutting up cedar wood for cigar boxes and in making parts of wagons and of machinery from ausobo. In the mountains in a few places old-fashioned whipsaw pits were seen, at which mahogany planks were being cut out of rough logs. These were then hauled by horses over muddy trails for many miles to the cities in which they were to be used. (See Pl. XIV, *C*.)

Aside from the few scattered hard-wood trees which grow on the slopes of the more inaccessible mountains there are a few rather extensive pieces of woodland. The most important of these is on the eastern end of the Sierra de Luquilla, which is heavily covered with virgin forest. East of Ponce, about Santa Isabel and Salinas and in the extreme southwest near Cabo Rojo, are some extensive areas of

AMEY (BREAD FRUIT) TREE IN FIELD OF YAUTIA RIO CANOVANAS

B, CLUMP OF BAMBOO, 60 FEET HIGH.

AR SUMMIT OF SIERRA DE LUQUILLA.

D CEIBA TREE IN FIELD OF GUINEA GRASS.

[redacted]

woodland. The amount of merchantable timber which is left, however, is too small to render this an important element among the natural resources of the island.

WATER POWER AND SUPPLY.

The volume of water available for utilization either as supply for domestic purposes in the various cities or for conversion into power through the agency of water wheels is relatively great. While this is especially true of the north side of the island, it applies also in a measurable degree to the south side, for, while on the latter side the streams do not discharge large volumes during the dry season, there is more water in them near their sources in the mountains than reaches the lowlands, because of loss through evaporation and percolation.

All of the cities of any size are provided with some form of domestic supply. At present, in San Juan, this is chiefly from rainfall. The same is true of most of the cities which are on the humid side of the island, though in some cases the rain water which is caught in tanks is supplemented by gravity supplies. In no city, however, is there a water supply of modern type at all commensurate with the requirements of a tropic climate. Not only is the supply for domestic use insufficient in every case, but there is practically no supply available for fire engines, for the flushing of house plumbing, or for washing streets and flushing gutters.

A new water supply is being provided for the city of San Juan. This was commenced under the Spanish authorities and is now being pushed to completion by officers of the United States. It is well designed after several years of survey and investigation. The supply comes from the Rio Piedras, about 6 miles above San Juan, where it is diverted into a short canal, which carries it into settling reservoirs, each of which has a capacity of one and one-half days' supply, at the rate of 35 gallons per head. Thence the water flows into filter beds, whence it is pumped to a distributing reservoir 110 feet high. From this it will be conducted in underground mains and distributaries to the various houses in the city.

Ponce receives a gravity water supply from the Rio Portugues, whence it is diverted about 9 miles above the city and conducted in masonry conduits and underground iron distributaries to the more important streets. On a hill back of the hospital in the outskirts of Ponce is a small, covered, distributing reservoir. This has not been cleaned in many years and is so foul that its use has been abandoned. Mayaguez, which is in fact the best provided city on the island, also receives a gravity supply. This is from the Rio Mayaguez, the perennial discharge of which is sufficient for the present requirements of the inhabitants.

Most of the smaller cities, as Aibonito, Adjuntas, Lares, etc., have gravity supplies of water piped to them from neighboring streams, but the volume of water supplied is rarely greater than can be easily carried in a 2-inch pipe. No difficulty either of an engineering or financial nature should be encountered in supplying these cities with abundant quantities of wholesome, potable water. Near every city there is sufficient water available in one or more of the rivers, and this can invariably be diverted at sufficient altitude to permit its being carried by gravity into the cities. The natural conditions in nearly every case are such as should insure the procurement of such water supplies at relatively small cost.

The opportunities for the generation of power are also superabundant, and the use which has thus far been made of them is insignificant. The amount of water available for conversion into power is evident from a consideration of the discharge of the various streams, as already stated, and the great height from which the water falls in but comparatively few miles. Streams which have a minimum volume of 50 to 150 second-feet at an altitude of 1,000 to 1,500 feet fall to within 100 feet of sea level in a distance of 5 to 10 miles. Consequently there are many steep rapids, cascades, and high falls in their courses, and it is necessary to convey the water in flumes or ditches but relatively short distances to obtain such head as will produce all the power of which use can be made. Finally, the width of the banks of these streams within the mountain gorges is so small and their surfaces are composed so largely of rocks and bowlders that there will be little difficulty or expense connected with the diversion of the water through dams and head works. Already one American corporation has purchased and obtained control of one or more water powers on the Rios Plata and Arecibo. The amount of power which will be obtained from these has been estimated as from 500 to 1,000 horse-power per concession.

TRANSPORTATION FACILITIES.

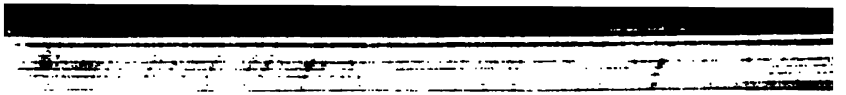
The development of the agricultural resources of the island is necessarily dependent largely on facilities for transporting products to the coast for shipment and of returning thence purchases made in the coast towns. At present the island is less adequately provided with good wagon roads than is the more sparsely inhabited and most inaccessible portion of the mountainous Western States. There is but one good road across the island and some pieces of fairly good road around the coast. The latter are, however, disconnected. In addition, there are about the coast several long but disconnected pieces of railroad. The railroads are of French construction and operation. They are of very narrow gage, 1 meter or less. There are about 140 miles of such railroad in operation, including a short stretch from San Juan eastward to Carolina; another from the same point westward

A. MUDDY CART ROAD NEAR ADJUNTAS.

B. MUDDY CART ROAD NEAR AIBONITO.

C. ROCKY CART ROAD NEAR LARES.

D. RUTTED CORAL ROCK IN CART ROAD NEAR SAN SEBASTIAN.



to a little beyond Arecibo; a section between Aguadilla, Mayaguez, and Hormigueros; one between San Sebastian and Añasco, and another from Ponce to Yauco. The locomotives are light, the cars small and of trifling capacity, and the trains run but once in every day or two and consist of but two or three cars.

The roads are divided into three classes: First, military roads, of which there are about 285 miles. These are all well graded and well surfaced with macadam and are kept in fairly good repair. (Pl. XIV, *D*.) Moreover, they cross the various drainage channels on well-constructed masonry bridges and culverts (see Pl. XVII, *A*), often girdling the mountain sides in great cuts, blasted out of the sides of the precipitous slopes (see fig. 10). Aside from the road from San Juan to Ponce, the other portions of this first-class road are near the coast, including a stretch between Arecibo, Aguadilla, and Mayaguez; another between Mayaguez and Yauco; and still others between Rio Piedras and Carolina and between Caguas, Juncos, Humacao, and Naguabo. A branch of the road which crosses the island extends from Cayey to Guayama. Aside from this limited amount of first-class road none on the island is worthy of being called even second class, though so designated by the Spanish.

FIG. 10.—Rockwork near Aibonito, summit of military road.

There are said to be about 100 miles of second-grade road, including stretches between Arecibo, Utuado, Adjuntas, and Ponce, of which only the latter portion is in condition to carry even the roughest cart traffic. (See Pl. XVI, *A*.) Another bit of cart road, over which only the lightest loads can be drawn by bullock, is between Aguadilla, San Sebastian, and Lares. (See Pl. XVII, *B*.)

The third class of roads, called cart roads, are officially stated as aggregating over 500 miles in length. None of these, however, is fit for other traffic than that of pack animals. Even military roads furnish transportation facilities for only an extremely limited extent of coun-

try to either side. The moment one leaves such roads he is compelled to enter at once on trails which climb the precipitous mountain sides with extremely steep grades or descend into the deep stream gorges.

The great amount of rainfall and the peculiarly slippery and sticky character of the red-clay soil on the humid side of the island renders all roads except those near the southern coast and those which are macadamized little better than impassable morasses. (See Pl. XVI, *B*.) No wheeled conveyance can travel such roads unless they be provided with far better drainage than now. On the drier side of the island, especially over the coral formation at the western end, the roads are filled with great rocks and bowlders (see Pl. XVI, *C*), and in places the soft coral rock is worn into deep ruts, rendering the roads impassable now for carts. (See Pl. XVI, *D*.) On these so-called cart roads even the sturdy pack animals have great difficulty in carrying relatively light burdens through clinging mud ankle deep, or over the bowlder and rock strewn surface.

As the bulk of the present transportation is on pack animals, which carry but 150 to 200 pounds a trip and return half laden, it is interesting to note the present price paid for handling freight in this manner. Between the more distant points over which pack journeys are made $1 per hundredweight is paid each way and 50 cents per hundredweight is the least rate, even for a very short haul. From the neighborhood of Adjuntas to Yauco and Ponce the rate is $1 per hundredweight. One of the largest coffee plantations on the island, that of Mariani Sons, pays from $1 to $1.50 per hundredweight for transportation. Those in the neighborhood of Lares pay as much as $2 per hundredweight for transportation to Mayaguez, and those of Tres Hermenos pay 75 cents per hundredweight. Sugar is conveyed from boiling houses to the nearest shipping points usually in 15-hundredweight hogsheads, which can be carried on bullock carts over the better roads found near the coasts. The cost for such haulage varies from 20 to 30 cents per hundredweight. Inferior as are the railroad facilities, the difference in price is shown by the fact that railroad carriage costs but two-thirds of a cent per hundredweight per mile.

The necessity for the development of a comprehensive system of first-class highways or railways is too evident to require further elaboration. Until such a system is in existence there is little hope for the development of any of the resources of the island except coffee and tobacco, which can be hauled at convenience, since they are not perishable, and sugar, which is grown only near the seacoast and at places convenient to shipping points. The most obvious direction in which improvement of internal means of communications should take place is in the construction of electric tramways as main arteries of traffic, supplemented by macadamized roads as feeders. Material for railway ballast and for road metaling is abundant in every part of the island. This consists chiefly of hard black limestone and of hard coral rock and bowlders.

A BRIDGE OVER RIO CANA NEAR [illegible]

B ROCKY CART ROAD NEAR LARES

INDEX.

Page.

gure showing method of dry-
offee at 38
owing road near 44
phy near 19
ass, plate showing view near
nit of 18
l land, types of 32
l products 34–41
gure showing military road
..... 45
owing road near 44
phy and flora near 17, 18
mmit, plate showing scenery
h of 18
owing view between Cayey
..... 18
, measurements of 28
owing view of 28
owing hills along 18
rto Rico 11
tion north and south through. 13
, measurements of 27
ent and use of 42
n route to market, plate show-
..... 40
te showing clump of 42
ltivation of 41
measurements of 27
te showing bridge over Rio
, near 46
phy near 16–17
ey, plate showing El Monte and 18
owing guinea grass in 32
io, measurements of 26
tio, measurements of 27
late showing bridge over, near
ias 46
Rio, measurements of 26
owing character of 16
owing field of yautia near 42
phy along the 16
measurements of 26–27
ate showing view of Rio Loiza
..... 26
din, plate showing 16
rts of 35
, and work done by 35–36
showing view between Aibo-
summit and 18
phy near 17
e, plate showing view west
..... 16
co district, figure showing cul-
ed hilltops in 37
, value of 42
plate showing 42
of Puerto Rico 21–24

Page.

Coamo, Rio, measurements of 27
Coastal topography of Puerto Rico 14–15
Coast, south, width and topography of 18
Cocoanut palm, cultivation of 41
Coffee, exports of 35
method of cultivating and drying, and value of 37–39
figure showing method of drying, at Adjuntas 38
plate showing method of shading 36
Coffee shelling, plate showing 36
Conduit for irrigation, figure showing 31
Conduit, plate showing river bed and masonry 32
Cordillera Central, coast limestone hills, and playa at Ponce, view of 15
course and altitude of 13, 14
Cotton, cultivation of 40
Cotton plant, plate showing 40
Crops in Puerto Rico, map showing distribution of 38
Culebrina, Rio, measurements of 28
Dam, wing, plate showing 28
Descalabrado, Rio, measurements of 27
plate showing view of 28
Ditch, irrigation, plate showing 32
plate showing regulator gate and 28
Drainage and hypsometric map of Puerto Rico 11
El Guilarte, height of 14
El Monte, plate showing Caguas Valley and 18
El Yunque, height of 12
plate showing view of 16
section north and south through 12
Exports from Puerto Rico 35
Fertilizers in Puerto Rico 33, 34
Flora, arid, near Lares, plate showing 26
diversity of, in Puerto Rico 23
Foothills of Sierra de Luquillo, plate showing 16
Forestry of Puerto Rico 41–43
Grass, varities grown in Puerto Rico 39–40
Guayama, section north and south through 13
Guinea grass, Caguas Valley, plate showing 32
plate showing field of 42
Hacienda Perla, rainfall at 22
temperature at 24
Hansard, A. C., observations made by 22, 23
quoted on height of El Yunque 12
Harrington, M. W., meteorologic data collected by 22
Hides, exports of 35
Hill, R. T., quoted on erosion in Puerto Rico 21
quoted on rocks of Puerto Rico 33
Honey, exports of 35

Page.
Hydrography of Puerto Rico 24-28
Hypsometric and drainage map of Puerto Rico 11
Irrigation ditch, plate showing 32
Irrigation in Puerto Rico 28-32
Jacaguas, Rio, irrigation from the 30-32
measurements of 27
plate showing view of, near Juana Diaz 16
Juana Diaz, plate showing barren hills near 20
plate showing view of Rio Jacaguas near 16
Land, agricultural, types of 32
Lares, plate showing arid flora near 26
plates showing roads near 44, 46
plate showing views near 22
topography near 19-20
Las Cruces, altitude of 17
La Torre, altitude of 19
plate showing view from summit of 22
Loiza, Rio, measurements of 26
plate showing view of 26
plate showing playa at mouth of 16
Luquilla, Sierra de. (*See* Sierra de Luquilla.)
Magueyes, Rio, measurements of 27
Mamey tree, plate showing 42
Mango trees bent by wind, plate showing 18
Map, drainage and hypsometric, of Puerto Rico 11
Map showing distribution of crops in Puerto Rico 38
Market scene, Ponce, plate showing 40
Mayaguez, water supply of 43
Military road. (*See* Road, military.)
Molasses, exports of 35
Mountain ranges of Puerto Rico 11-14
Mountain summits under cultivation, plate showing 34
Oranges in Puerto Rico 41
Ox cart, plate showing 34
Pack animals, cost of transportation by 46
Pack horse, plate showing 34
Parting valley about and hills back of Yauco, plate showing 26
Piedras, Rio, water supply furnished by 43
Piloncillos, near Lares, view of 20
Pineapples, cultivation of 41
Plantain, cultivation of 40-41
Plata, Rio, measurements of 27
Playa at mouth of the Rio Loiza, plate showing 16
Playa, description of 16
Ponce, plate showing market scene at 40
plate showing sugar land near 32
plate showing view of Rio Portugues at 26
section north and south through 13
topography near 18-19
water supply of 43
Portugues, Rio, plate showing view of 26
measurements of 27

Page.
Portugues, Rio, water supply furnished by 43
Precipitation in Puerto Rico 22-24
Products, agricultural, of Puerto Rico 34-41
Railroads in Puerto Rico 44-45
Rainfall in Puerto Rico 22-24
Regulator gate and ditch, plate showing 28
Rice, cultivation of 40
Rio. (*See* next word of name.)
Road, military, near Aibonito, figure showing ..... [illegible]
from San Juan to Ponce, course of and topography along ..... [illegible]
plate showing method of repairing ..... [illegible]
Road near Adjuntas, plate showing 44
Road near Aibonito, plate showing 44
Road near San Sebastian, plate showing 44
Roads in Puerto Rico 45-46
Roads near Lares, plates showing 44, 46
San Juan, plate showing bent mango trees at 18
rainfall at 22
section north and south through 13
water supply of 43
San Sebastian, plate showing road near 44
Section north and south through El Yunque 12
Section north and south through Ponce 13
Section north and south through San Juan 13
Sierra de Cayey, course and elevation of 12
Sierra de Luquilla, extent and course of 12
plate showing foothills of 16
plate showing view near summit of 42
topography of 16
Siphon, figure showing inverted, carrying ditch under military road 30
Soils of Puerto Rico 32-33
Streams, number and measurements of 24-28
Sugar, exports of ..... [illegible]
method of cultivating ..... [illegible]
Sugar cane, plate showing ..... [illegible]
trains of cars loaded with, plate showing ..... [illegible]
Sugar land near Ponce, plate showing ..... [illegible]
Temperature of Puerto Rico ..... [illegible]
Tobacco, cultivation and value of ..... [illegible]
exports of ..... [illegible]
figure showing cultivation on hillsides in Cayey district ..... [illegible]
Topographic features of Puerto Rico ..... [illegible]
Trade winds, influence of ..... [illegible]
Transportation facilities in Puerto Rico ..... [illegible]
Turabo, Rio, measurements of ..... [illegible]
Water power and supply in Puerto Rico ..... [illegible]
Winds, trade, influence of ..... [illegible]
Wing dam, plate showing ..... [illegible]
Woods of Puerto Rico ..... [illegible]
Yahueca, Rio, measurements of ..... [illegible]
Yauco, plate showing parting valley about and hills back of ..... [illegible]
Yautia, plate showing field of ..... [illegible]
cultivation of ..... [illegible]

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